Ecological indicators for Washington State's outer coastal waters

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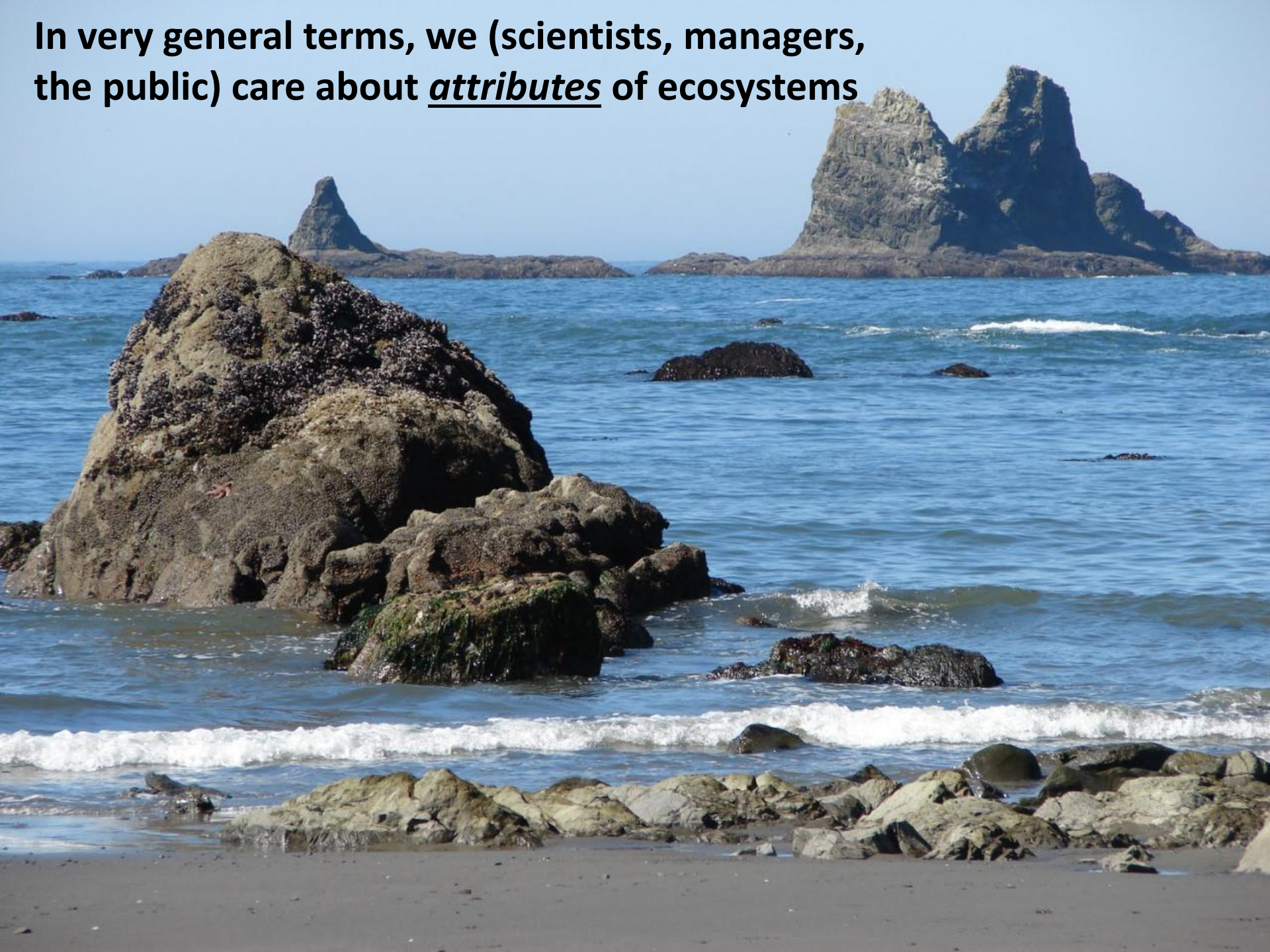

In very general terms, we (scientists, managers, the public) care about *attributes* of ecosystems

Why we need ecological indicators:

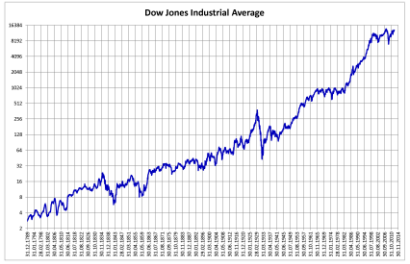
- **“Attributes” are hard to measure!**

- **Mandate! Washington Marine Spatial Planning legislation (2010) requires development of indicators to:**
  - Assess “the *health* and trends of the ocean ecosystem.”
  - Detect changes in components of the ecosystem that we care about

What is an ecological indicator?

- Empirically tractable metrics that reflect the status or trend in ecosystem attributes
  - Status: where are we now?
  - Trend: where are we going?

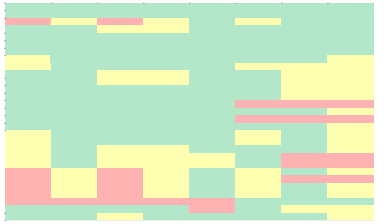
- Examples of indicators in other fields:
  - Human Health: Blood pressure, Body temperature
  - Economics: Unemployment rate, Housing starts
  - World Health: Infant mortality rate, Immunization (%)
  - Public Safety: Homicide rate, Traffic accidents per capita
  - Education: Adult literacy rate, Expenditures as %GDP



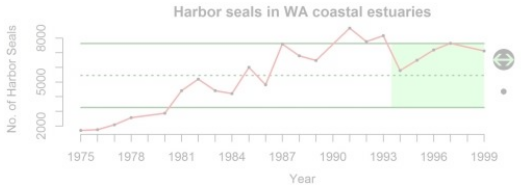
Assessing the "health" of WA coastal ecosystems for marine spatial planning

1. Develop conceptual models of the key physical, ecological and human activities in habitats of the outer Washington coast.

2. Evaluate and select a portfolio of indicators for the key components of the conceptual models.



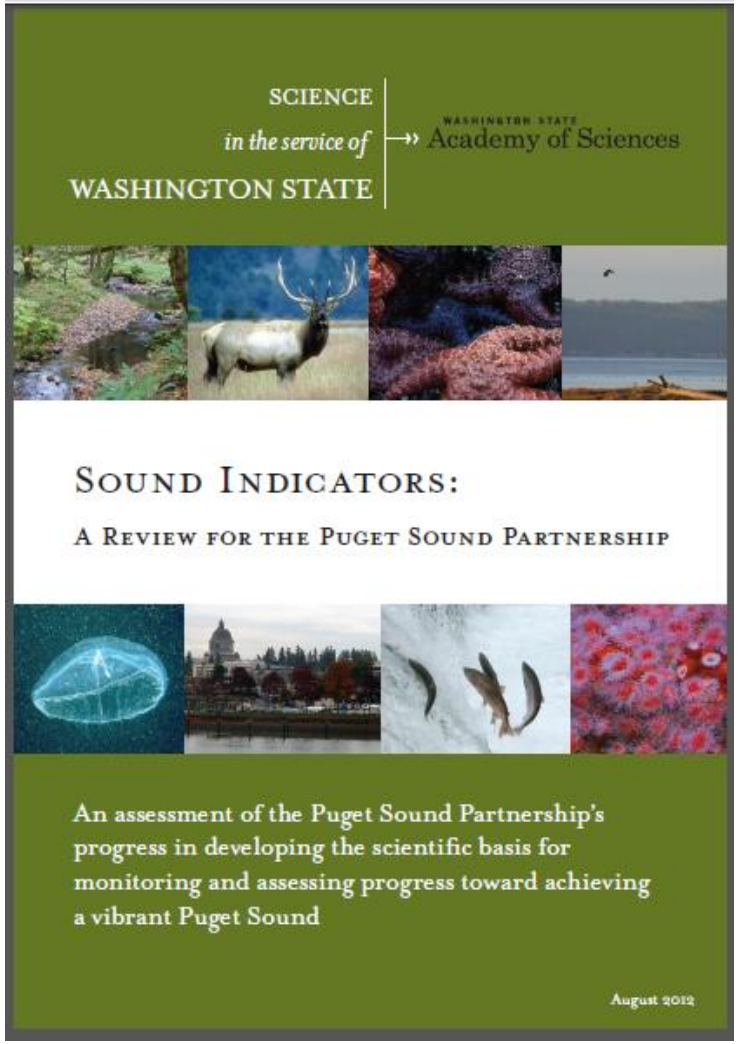
3. Quantify the status and trends of these indicators.



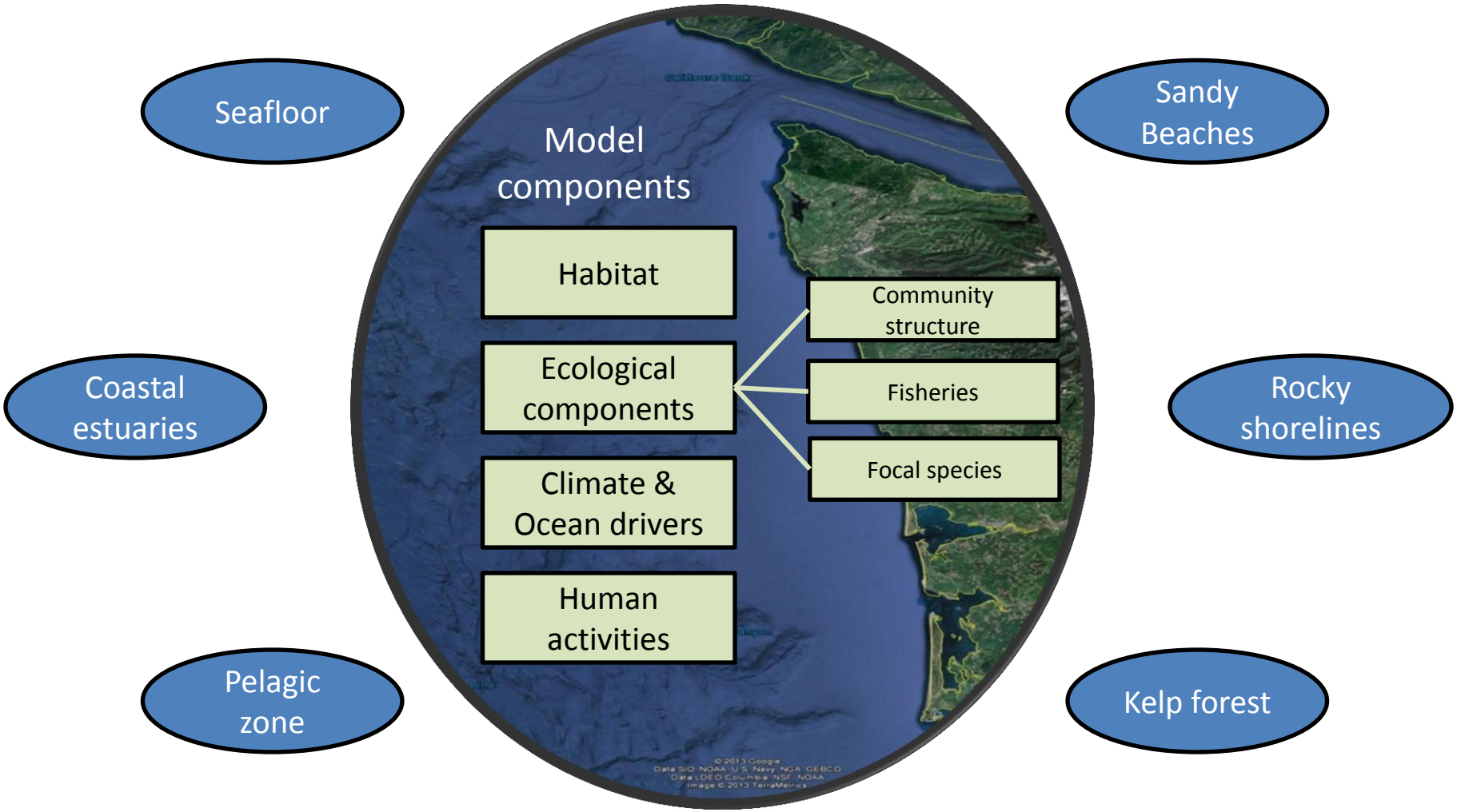
Washington Academy of Sciences report on development of ecosystem indicators by the Puget Sound Partnership (Orians et al. 2012)

- Reviewed the process for selecting indicators by the Partnership
- Part of that process included the same indicator screening protocol we are using in the IEA

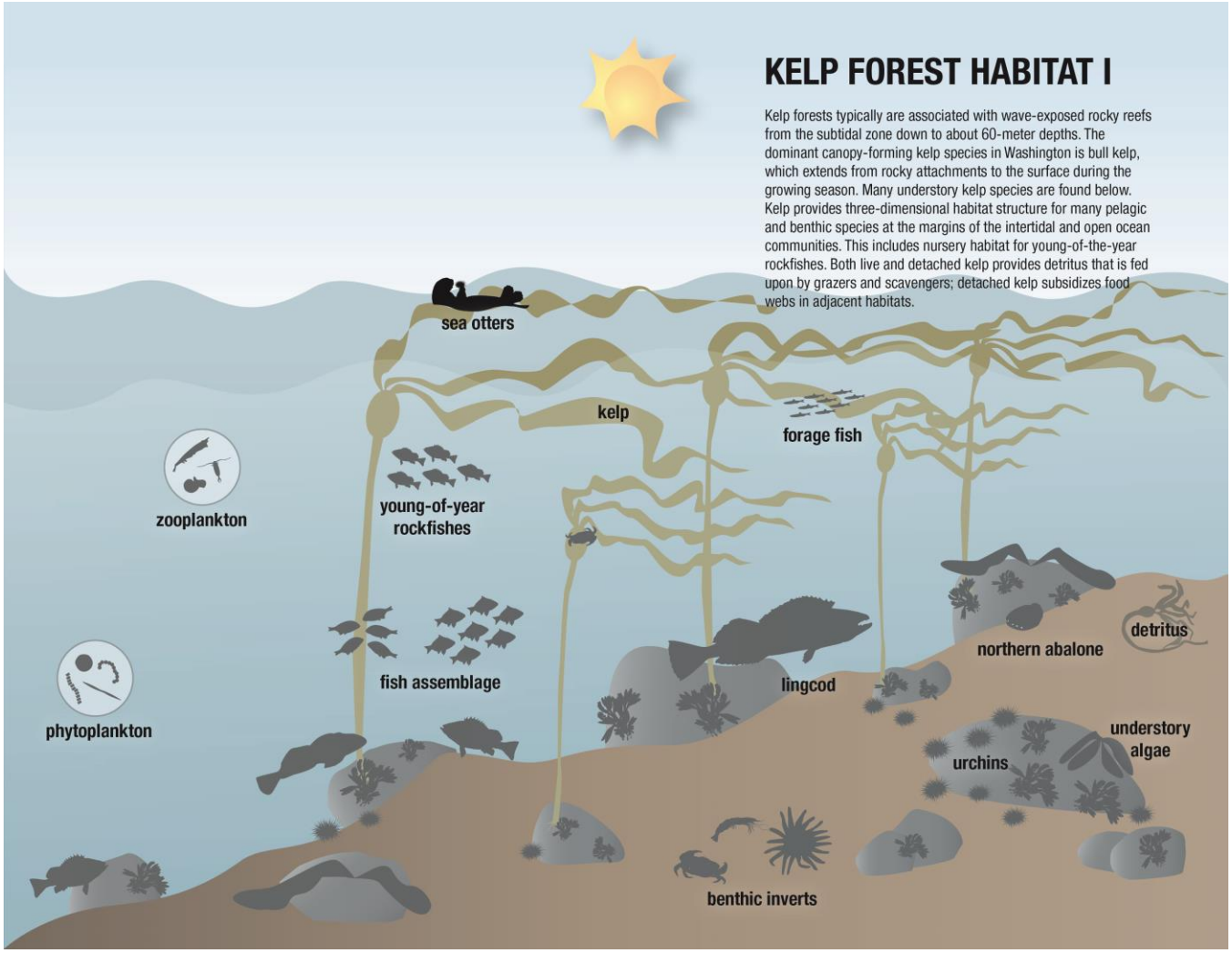
*"…**it is paramount to begin with a conceptual model** of the ecosystem being evaluated, and to use this understanding to guide the selection of indicators that represent the important attributes of the system."*



Conceptual framework for selecting ecological indicators



Conceptual models



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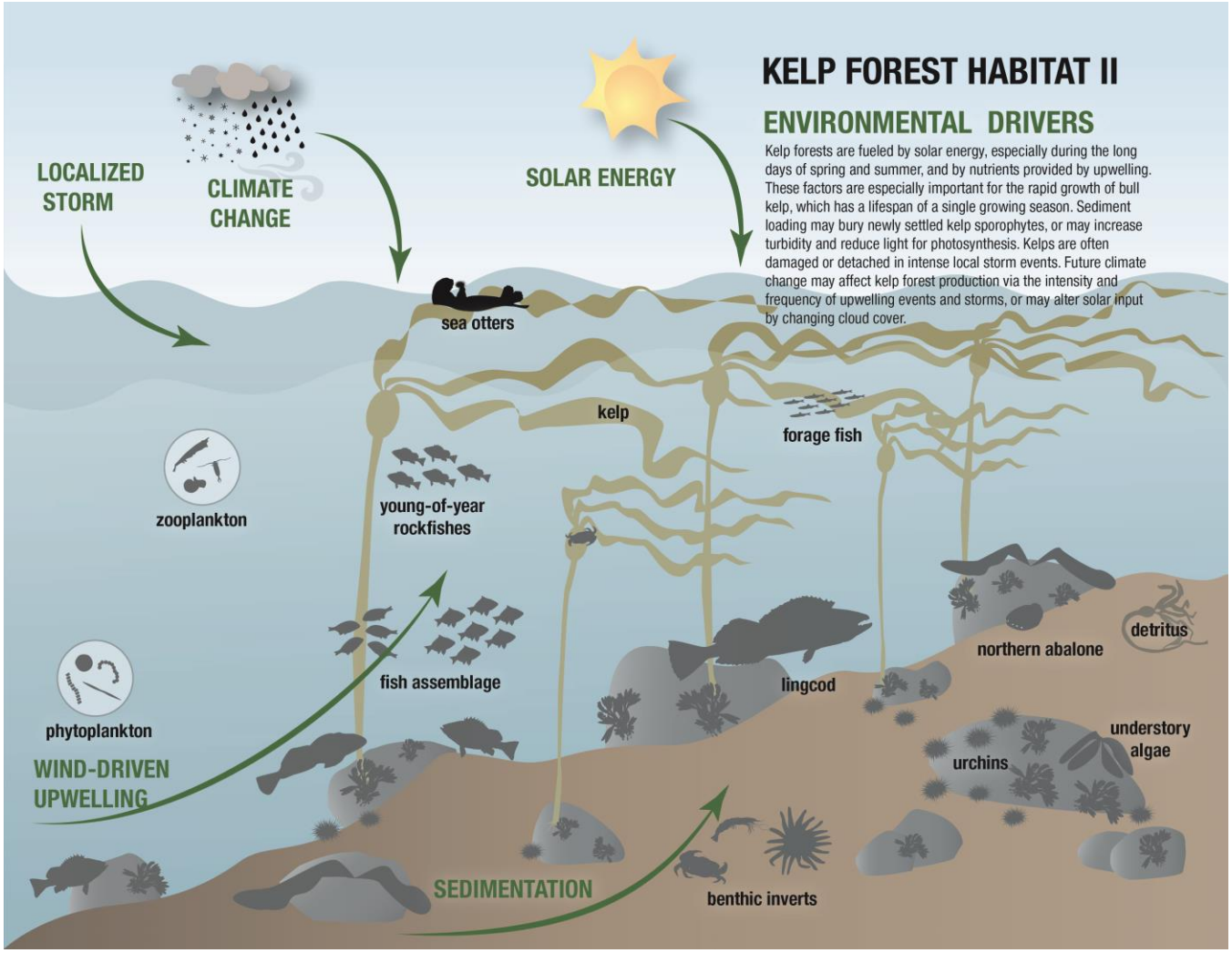

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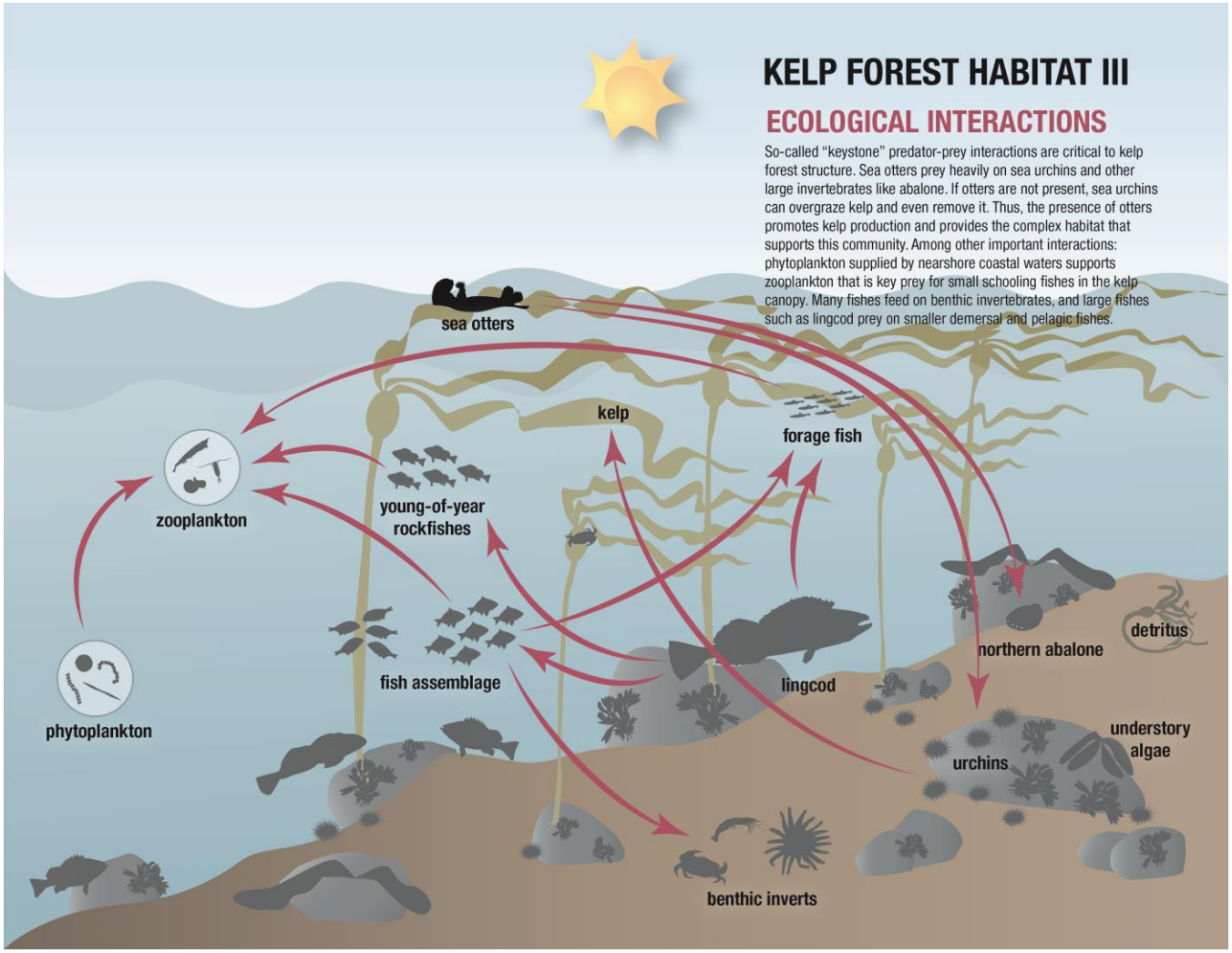

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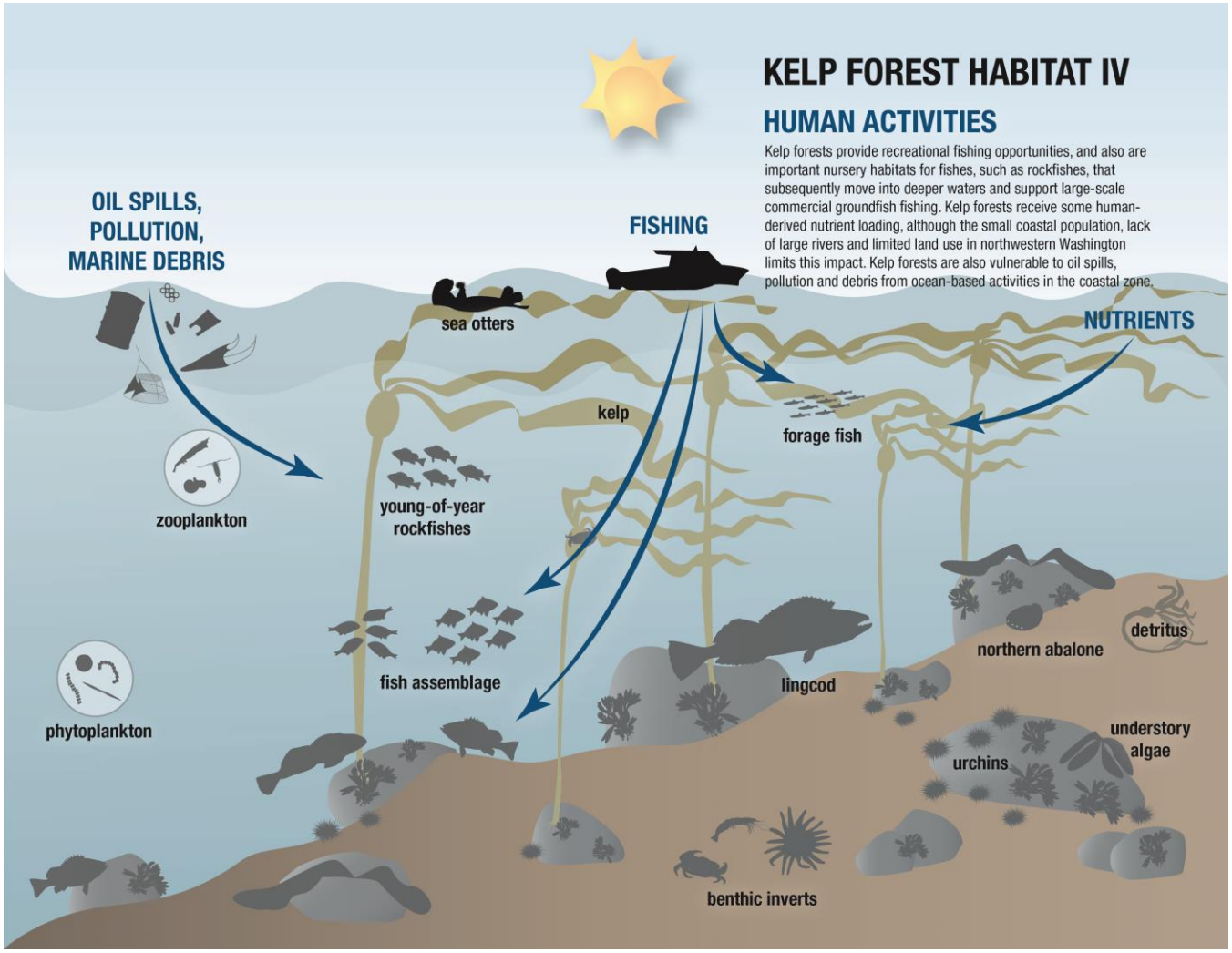

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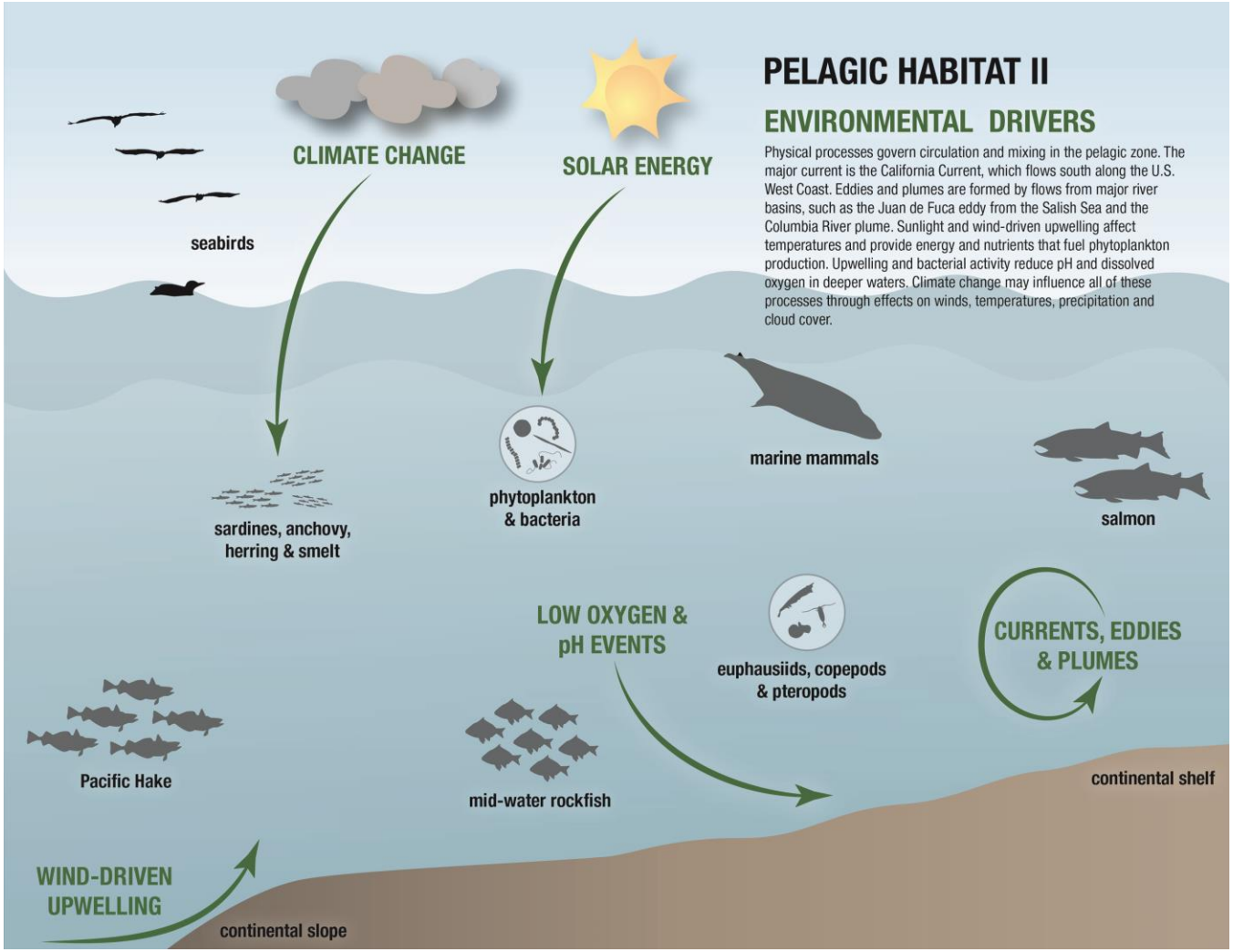

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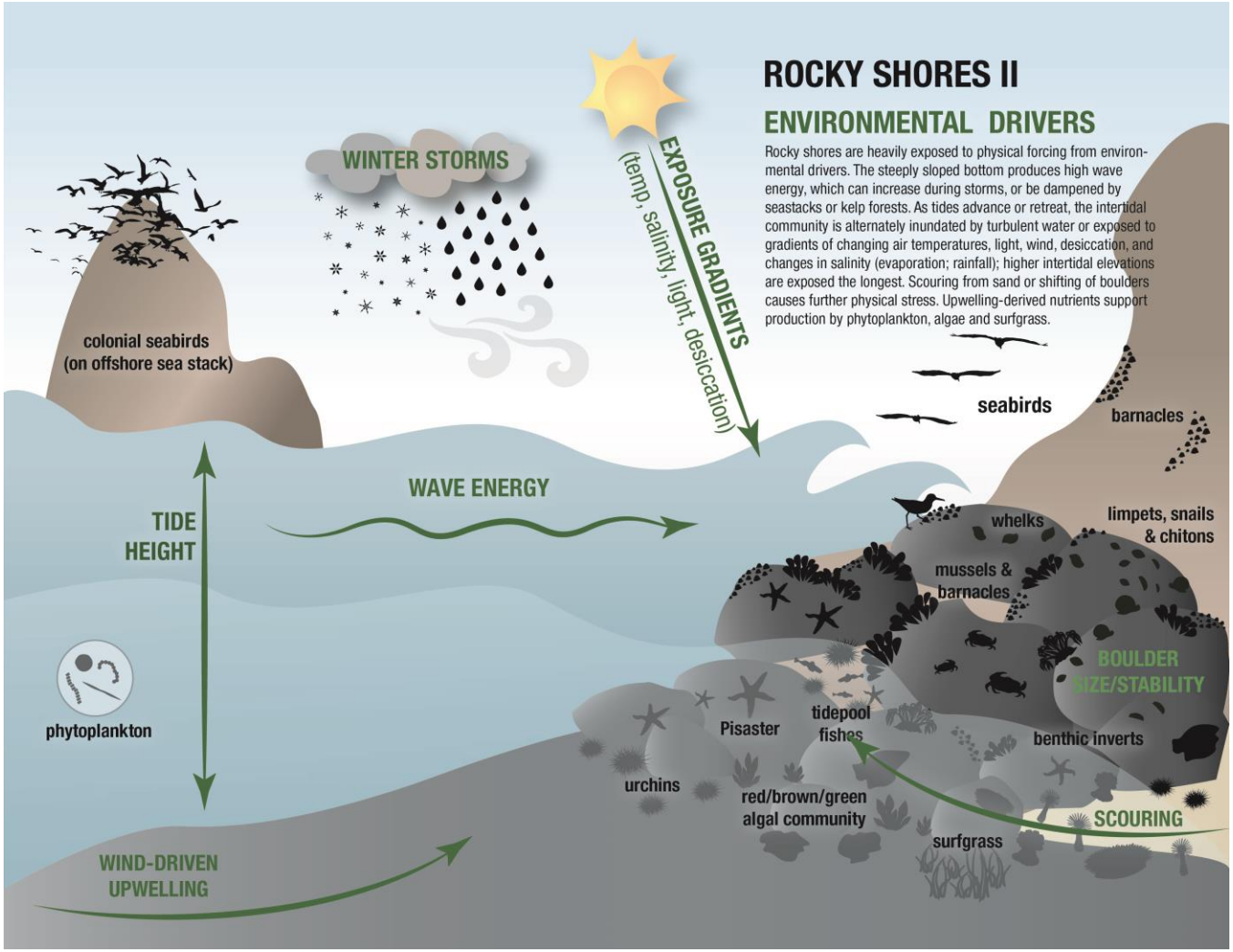

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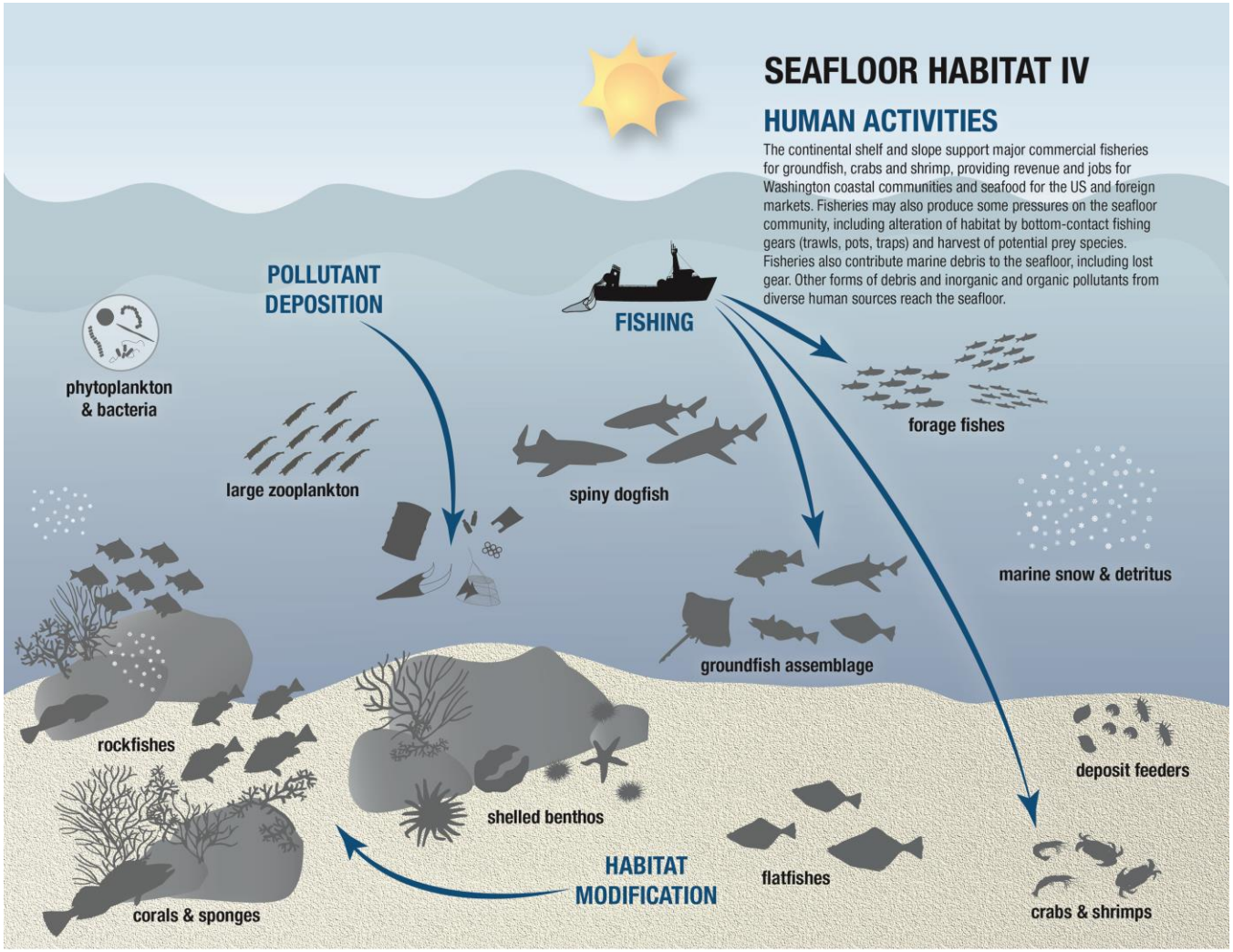
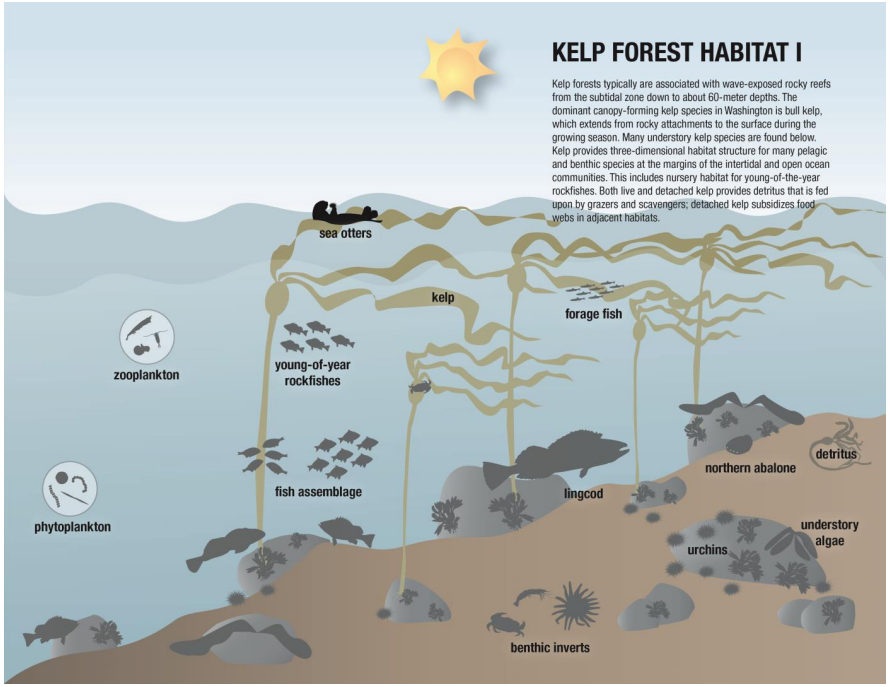
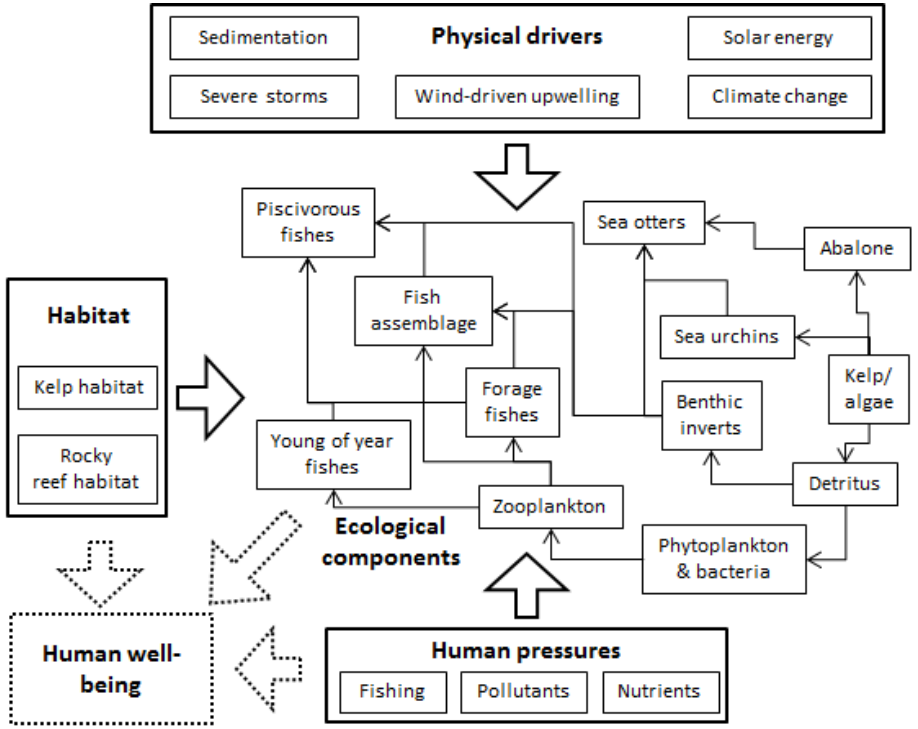


All “illustrative” conceptual models have “analytical” counterparts





Each box and arrow should have at least one indicator associated with it!

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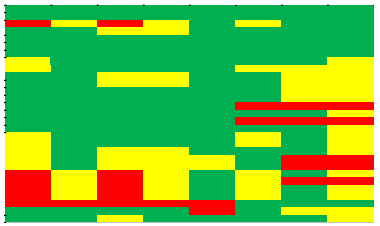

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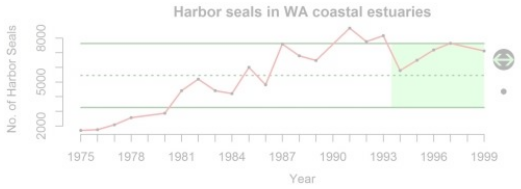
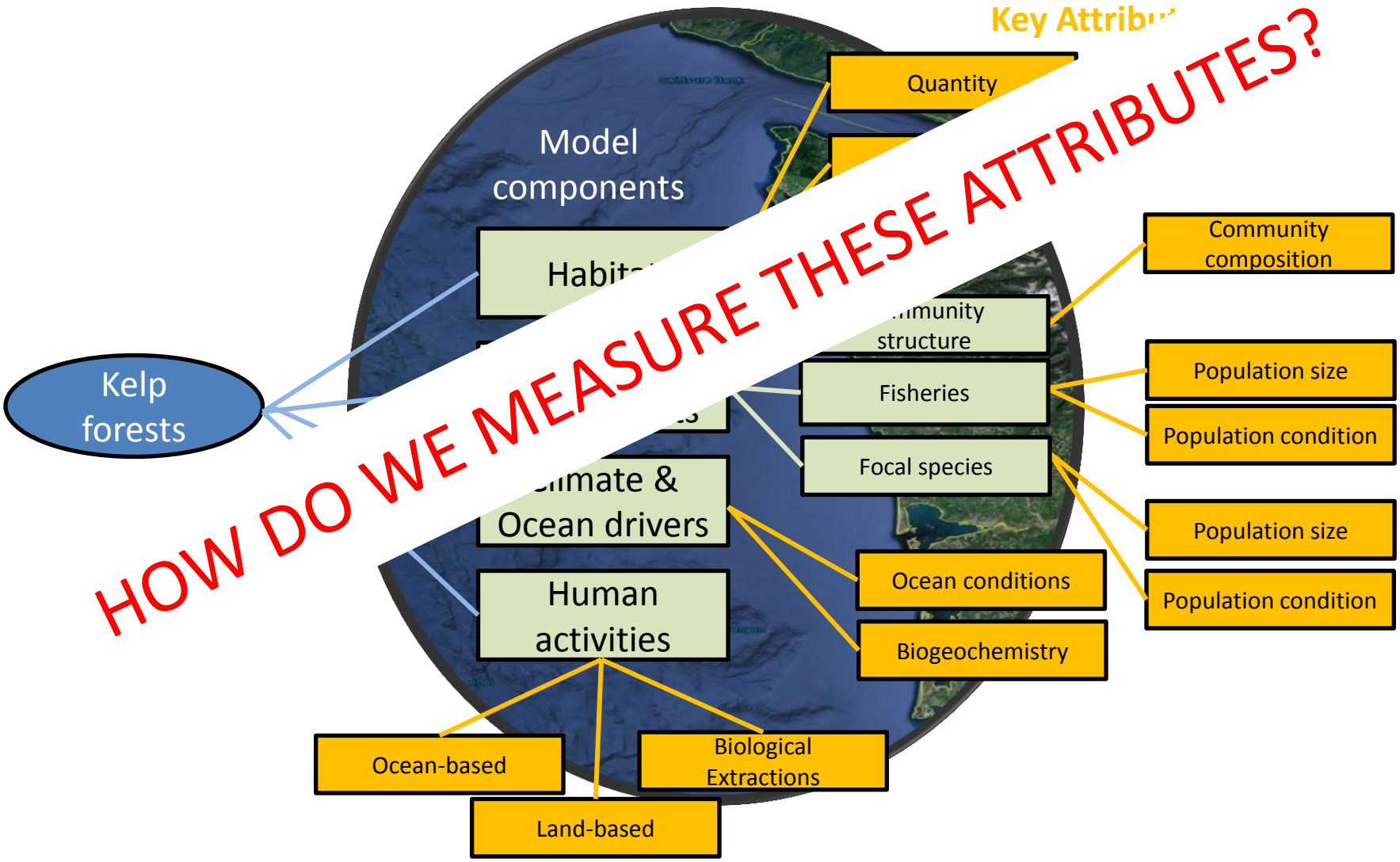
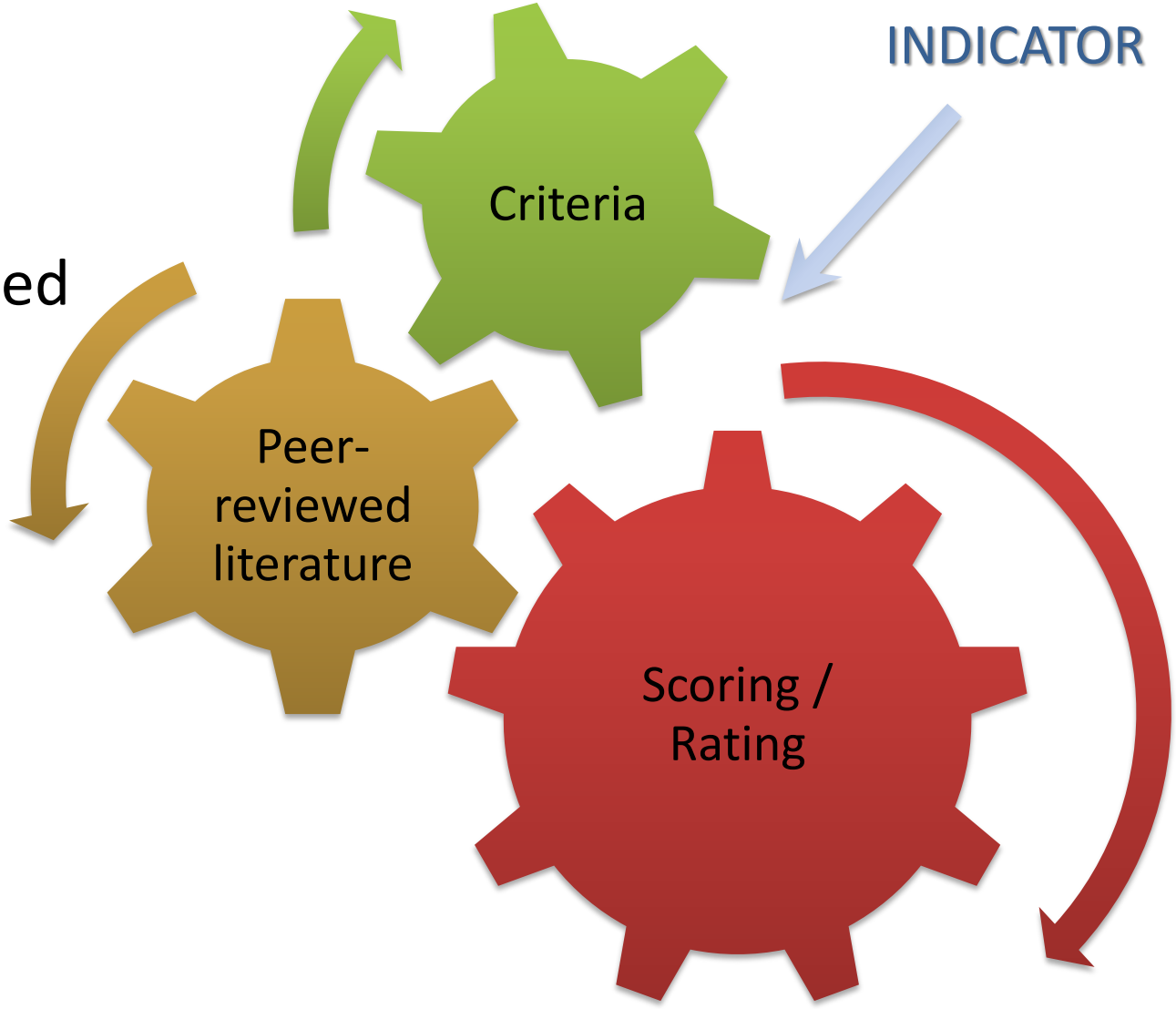


Indicator Evaluation Process



Indicator Evaluation Process

- Transparent
- Repeatable
- Defensible
- Readily Updated



Step 1: Identify Indicators

Compile a list of 100s of potential indicators that could be used to measure key attributes in each conceptual model.

– Examples of potential indicators for kelp forest:

- **Ecological components**
  - **Fisheries taxa**

    - **Lingcod population size**
      - Abundance
      - Landings
    - **Lingcod population condition**
      - Age structure
      - Genetic diversity
  - **Focal species**

    - **Sea otter population size**
      - Abundance
    - **Sea otter population condition**
      - Birth rates

- **Human activities**
  - **Ocean-based**

    - **Extractions**
      - Commercial fishery landings
      - Recreational fishery landings
      - Derelict gear

    - **Commercial shipping**
      - # of vessel trips
      - Port volume
      - Volume of water disturbed

Step 2: Screen each indicator with criteria

Indicator Evaluation Criteria (Kershner et al. 2011)

Primary considerations (5)	Data considerations (7)	Other considerations (5)
• Theoretically sound • Relevant to management concerns • Responds to changes in attributes • Responds to changes in management • Linkable to targets	• Concrete and numerical • Historical data • Simple • Broad spatial coverage • Continuous time series • Spatial & temporal variation understood • Signal-to-noise ratio	• Understood by the public • History of reporting • Cost-effective • Anticipatory • Compatible (regional, national, international)

- **Indicators will then be "rated" for each criterion based on information in the peer-reviewed literature**

Step 3: Literature-based scoring

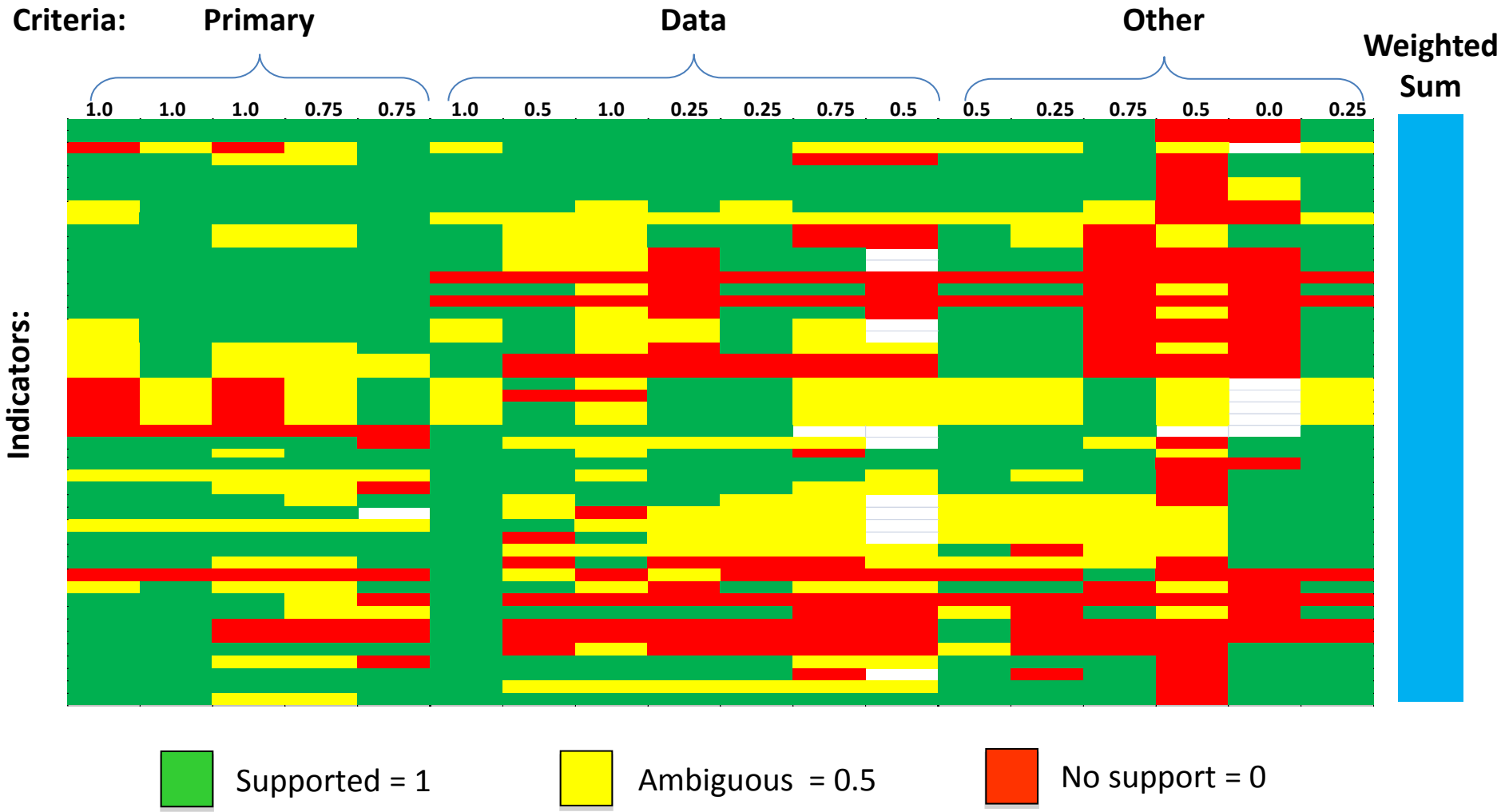
Step 4: Criteria weighting

- Not all criteria are equally important
- Polled 35 scientists, managers, and stakeholders from Washington State.
- Experts ranked each of the 17 criteria from 0 (“not important”) to 1 (“highly important”)

Theoretically sound?	Spatial & temporal variation understood?	Easily understood by public?
1	0.75	0.5

Etc. …

Step 4: Criteria weighting



Final tables for each habitat (ex.: seafloor)

Table 5. Summary of indicators and times series duration for each component's key attributes for WAMSP seafloor habitat. † indicates data are presently being analyzed.

Component	Attribute	Indicator	Time period of available data
Physical drivers			
Climatic	Water temperature	Seafloor temperature	2003 – 2014
		Pacific Decadal Oscillation	1900 – 2015
	El Niño events	Multivariate El Niño Index	1950 – 2015
		Northern Oscillation Index	1948 – 2014
	Source waters	North Pacific Gyre Oscillation index	1950 – 2015
		Northern copepod anomaly	1996 – 2015
Oceanographic	Upwelling	Upwelling index	1967 – 2014
		Spring transition index	1967 – 2015
	Currents, eddies, plumes	Columbia River plume volume	1999 – 2014
	Low dissolved oxygen (DO) events	DO continental shelf/slope	2009 - 2014
		DO at Newport, OR, 150 m	1998 - 2014
		Area of hypoxia (Sept)	2006 - 2012
Habitat			
Physical and biogenic habitat	Quantity	Substrate type map	NA
		Biogenic habitat map	NA
	Quality	Seafloor temperature	2003 – 2012
		DO continental shelf/slope	2009 - 2014
		DO at Newport, OR, 150 m	1998 - 2014
		Area of hypoxia (Sept)	2006 - 2012
Ecological components			
Phytoplankton and bacteria	Population size	Phytoplankton biomass	NA†
	Population condition	Diatoms: dinoflagellate ratio	NA†
Zooplankton	Population size	Prey field index	1999 - 2014
		Aggregate biomass	NA†
	Population condition	Northern copepod anomaly	1996 - 2015
Marine snow and detritus	Population size	Not yet evaluated	NA
	Population condition	Not yet evaluated	NA
Benthic invertebrates	Population size	Aggregate biomass	NA
	Population condition	Spatial structure/distribution	NA†
Crustaceans	Population size	Crab abundance (CPUE)	2003 - 2013
	Population condition	Condition factor (K)	2006 - 2014
Forage fishes		Section under development	NA
Groundfish	Population size	Groundfish spp. abundance (CPUE)	2003 - 2013
	Population condition	Groundfish spp. size/age-structure	2003 - 2014
Ecosystem health	Biodiversity	Simpson's diversity	2003 - 2013
		Species richness	2003 - 2013

Component	Attribute	Indicator	Time period of available data
	Trophic structure	Mean trophic level of groundfish	2003– 2013
		Northern copepod anomaly	1996 - 2015
		Ratio of scavengers to total biomass	2003 - 2013
Human activities			
Biological extractions	Fishing	Fisheries landings	1981 - 2014
Ocean-based activities	Seafood demand	Seafood consumption	1962– 2013
	Habitat modification	Distance trawled	1999 - 2012
Land-based activities	Pollution	Atmospheric	1994– 2014
		Organic	1993 - 2010
		Inorganic	1988 – 2013
		Marine debris	1999 - 2007

PHYSICAL DRIVERS

CLIMATE VARIABILITY

SEAFLOOR TEMPERATURE

Temperature is one of the most important drivers in the ocean. Ocean temperature regulates the rate of metabolism for most organisms and regulates the base of the food web. In WAMSP waters, cooler temperatures generally result in a prey base that contains energy-rich northern species, which promote high growth in consumers, whereas warmer temperatures generally promote southern species that are of much lower nutritional quality (Hooff and Peterson 2006, Peterson 2009). As indicators of ocean temperatures in WAMSP waters, we selected seafloor temperatures off the Washington coast as measured during the NWFSC's Groundfish Bottom Trawl Survey of the continental shelf and slope from 55 – 1280 m during the summer months, and the Pacific Decadal Oscillation (PDO) as a broad-scale indicator of changes in ocean temperatures in the North Pacific. Over the last five years, seafloor temperatures across the continental shelf and slope showed no trend, whereas the PDO shifted from a cool phase to a warm phase (Figure 30).

Detail from seafloor final indicator table

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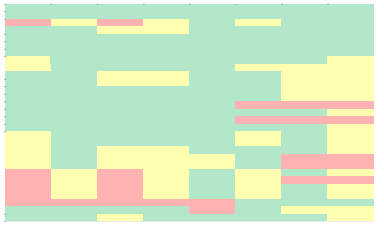

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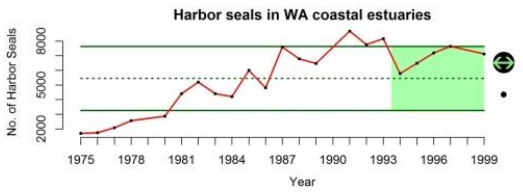
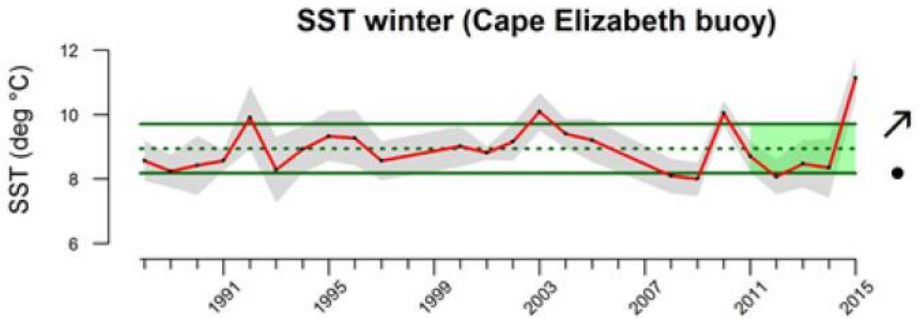
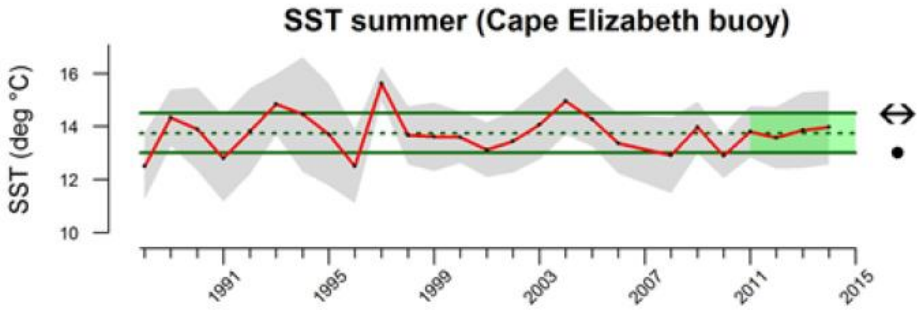
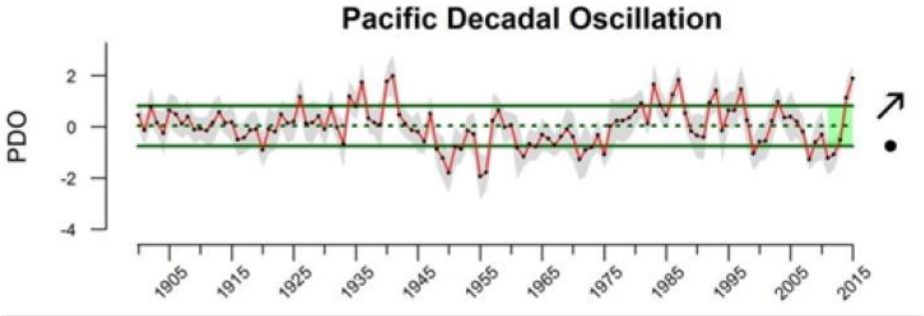


Two ways to track status and trends

1. Temporally

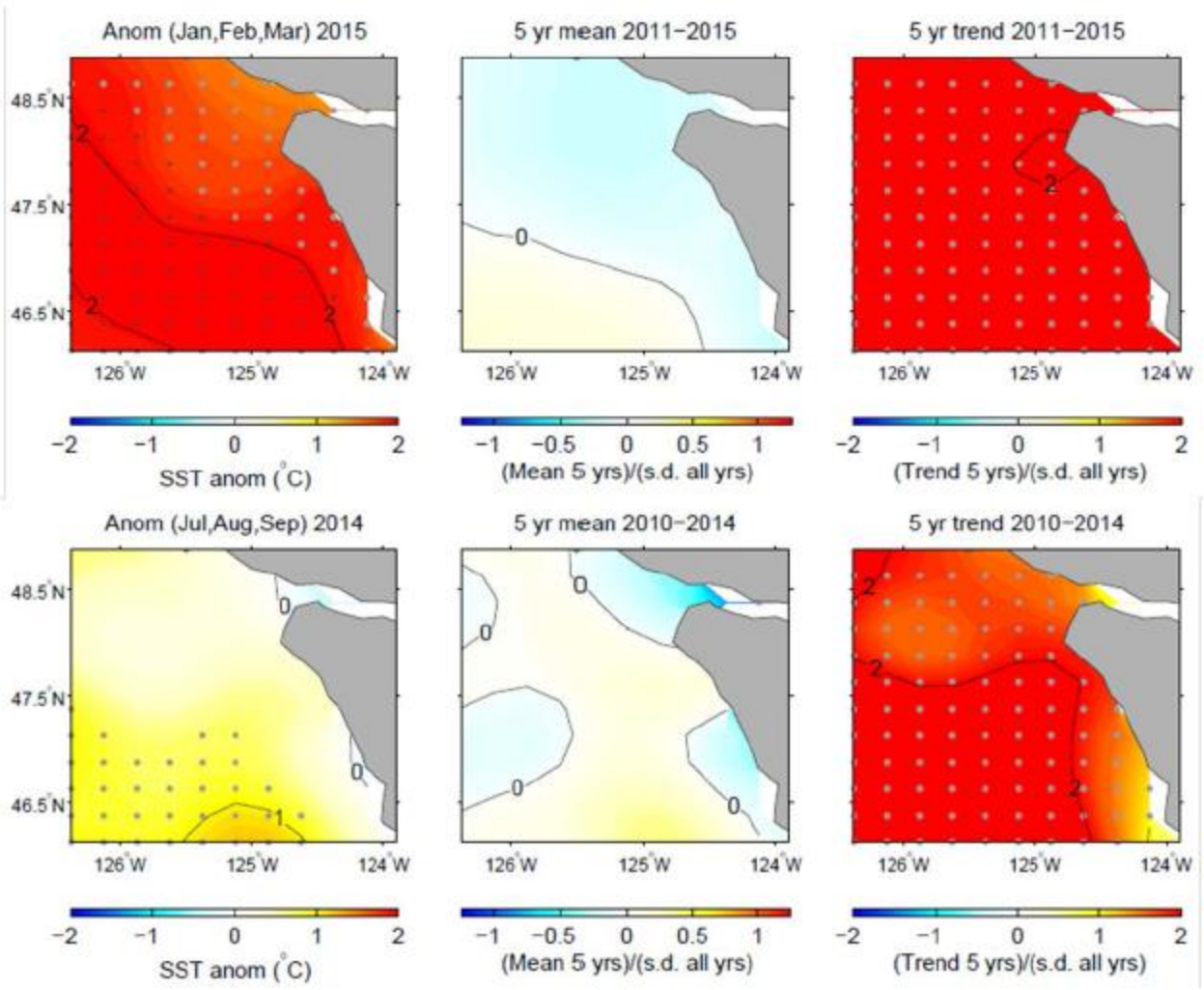






Two ways to track status and trends

2. Spatiotemporally



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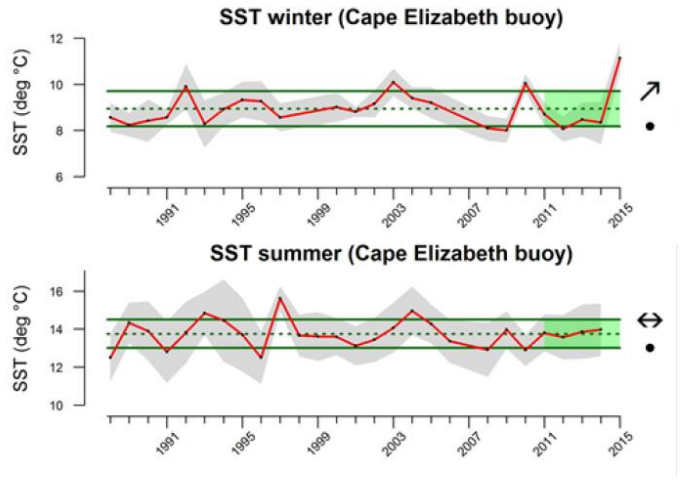
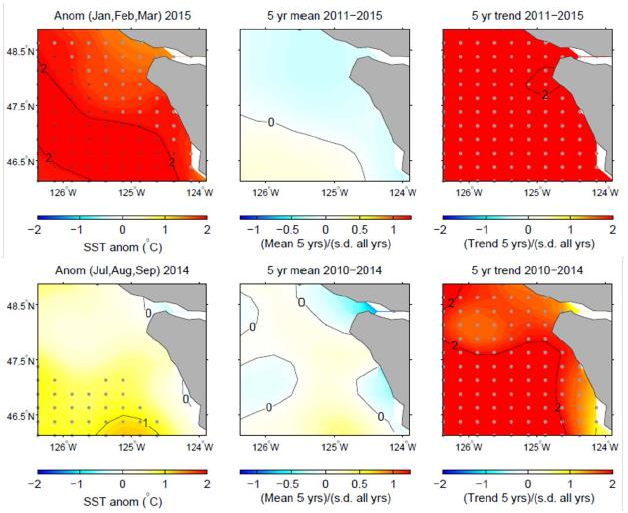


vs.

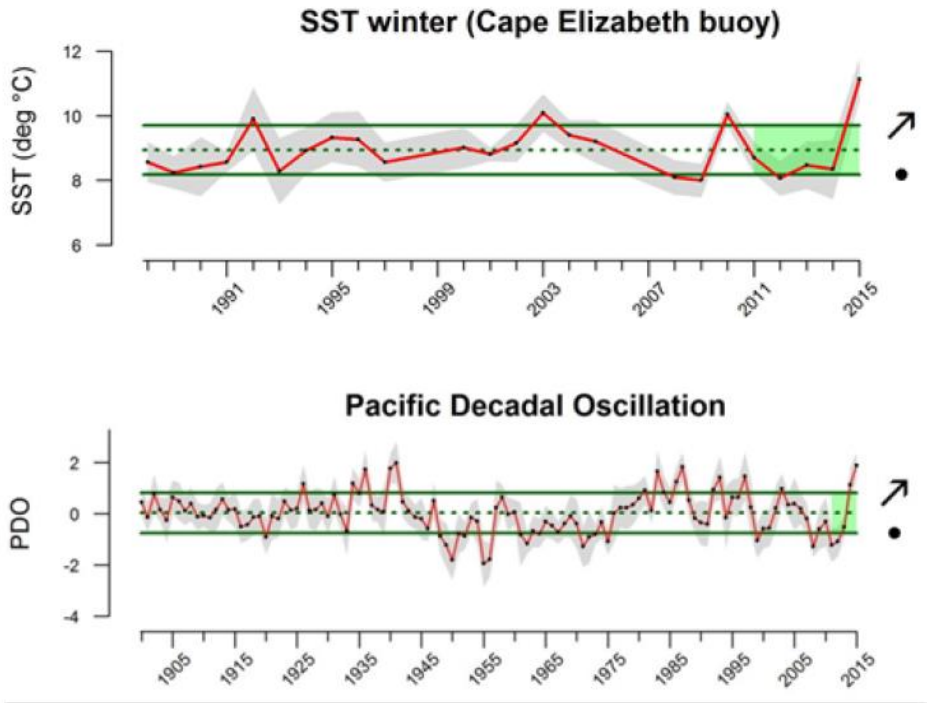


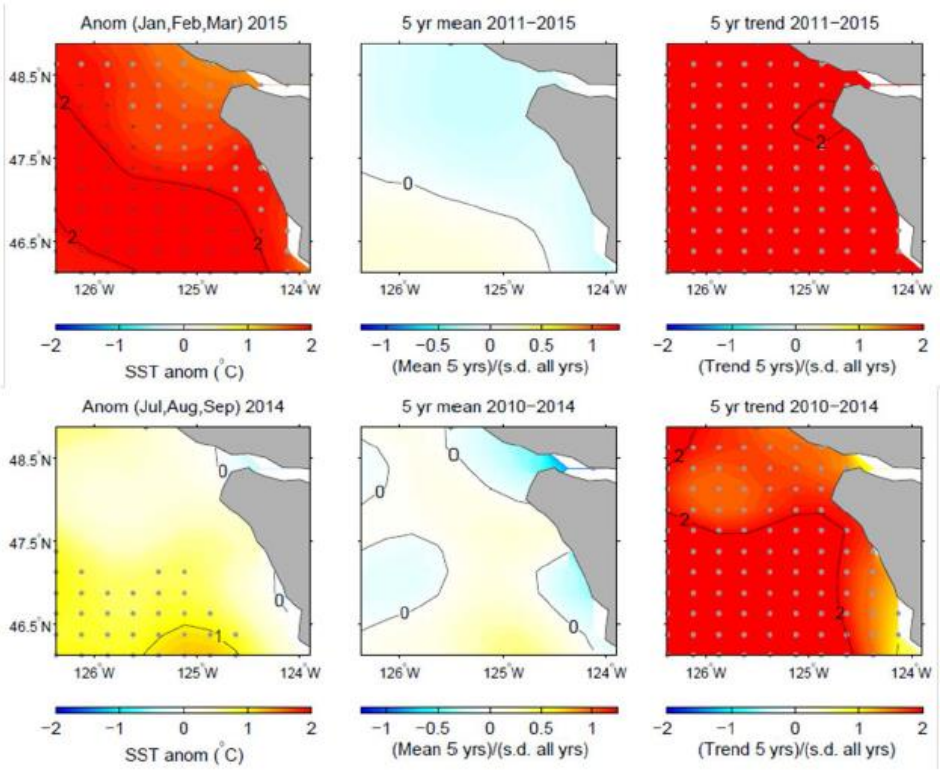
- **VASTLY** more often than not, our status & trends plots are temporal (left)
- As much as anything, that's an issue of the way monitoring is currently done, at index sites
- MSP approach likely will require more focus on spatiotemporal data, but the indicators themselves are (we hope) robust
- OCNMS Condition Reports may be able to use both approaches

Highlights

Some status & trends highlights: pelagic

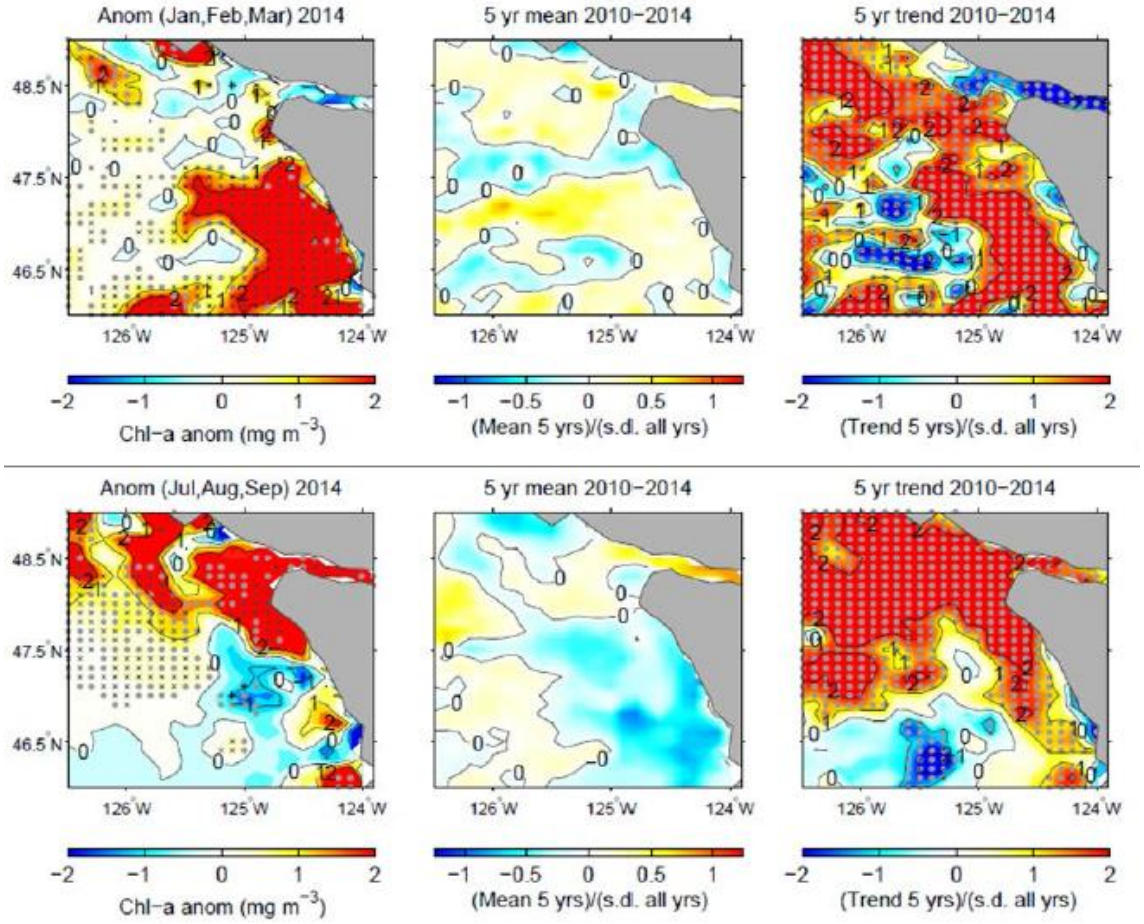
- SST = highly ranked indicator of climate drivers, habitat quality
- It's been getting warmer





Some status & trends highlights: pelagic

- **Key indicators of ecological integrity (food web "health"): chrorophyll a and abundance of northern copepods**
- **A transition may be occurring…**



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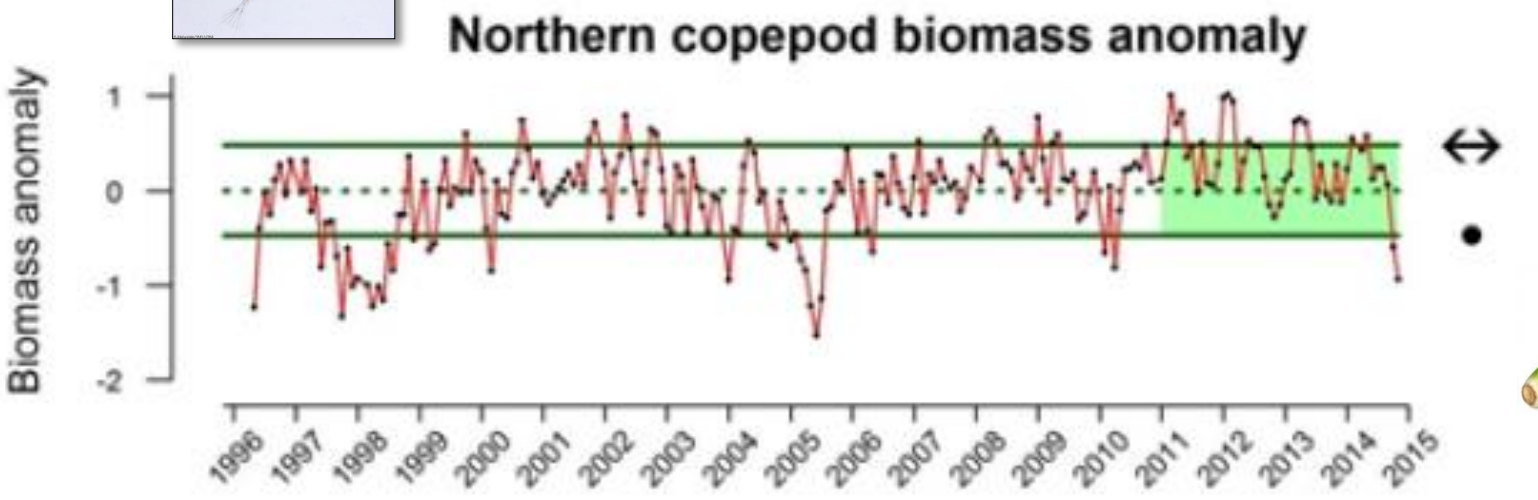
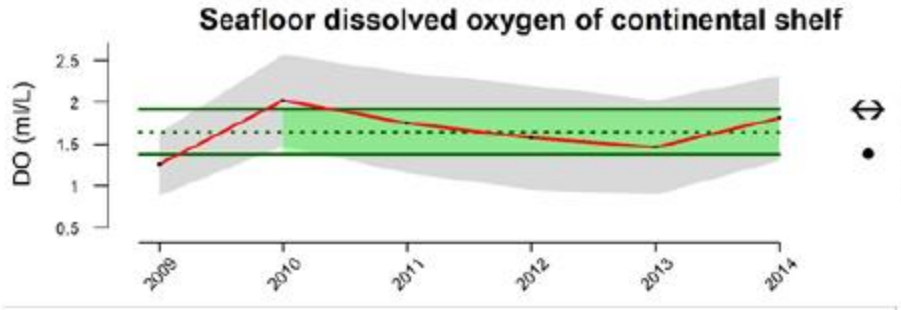
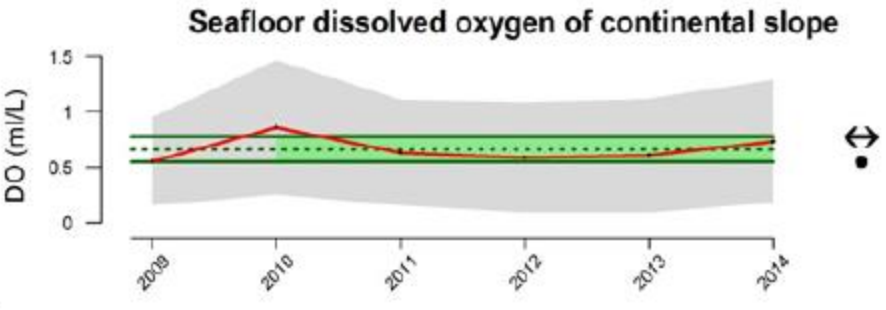
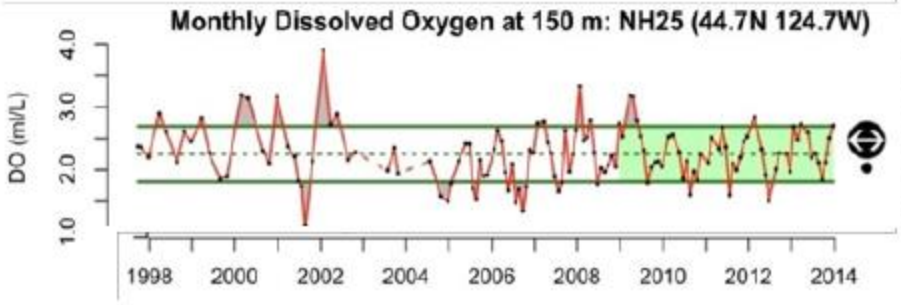


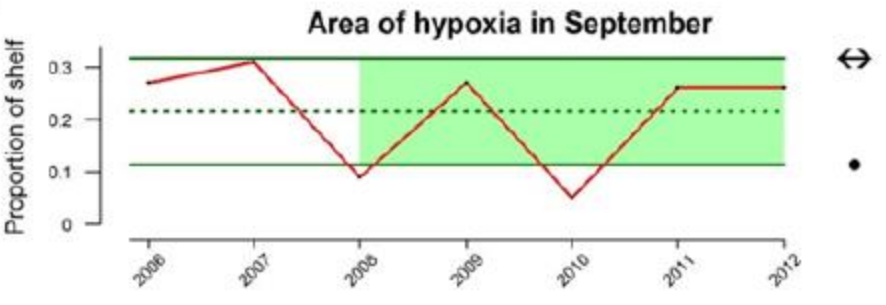
Some status & trends highlights: seafloor

- **DO = highly ranked indicator of oceanographic drivers, habitat quality**
- **No real surprises here, I don't think, though many of these time series are short and not terribly spatially refined yet**



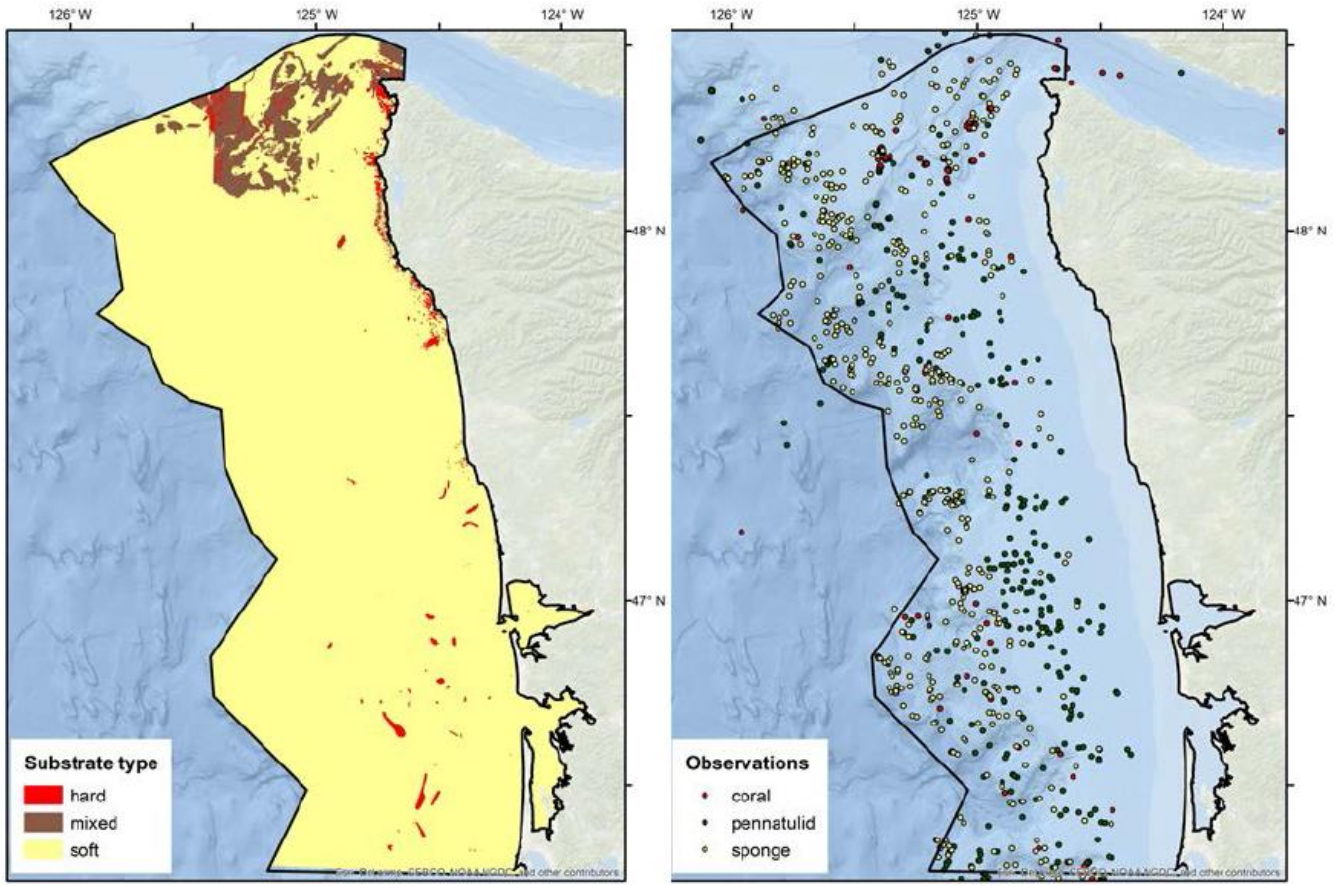






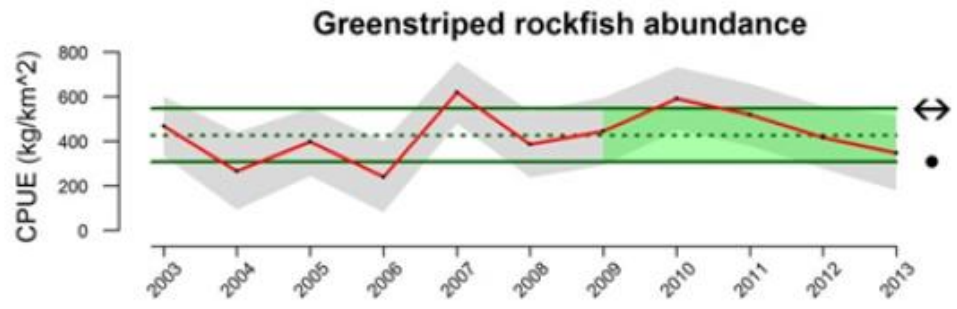
Some status & trends highlights: seafloor

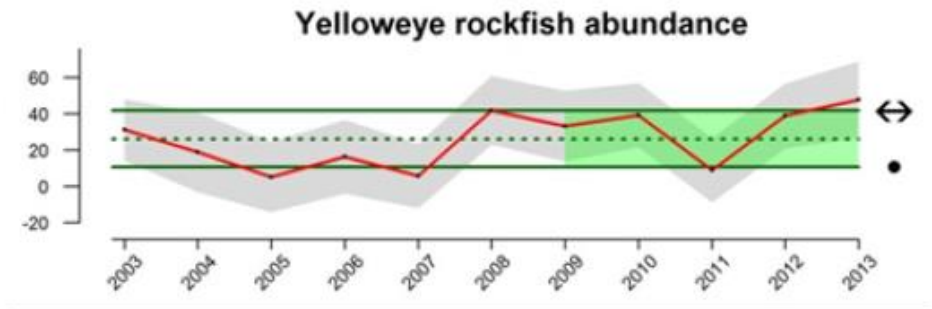
- **Substrate and biogenic habitats rated highly for habitat quantity**
- **We mainly have a snapshot, from EFH work, but it's a start**

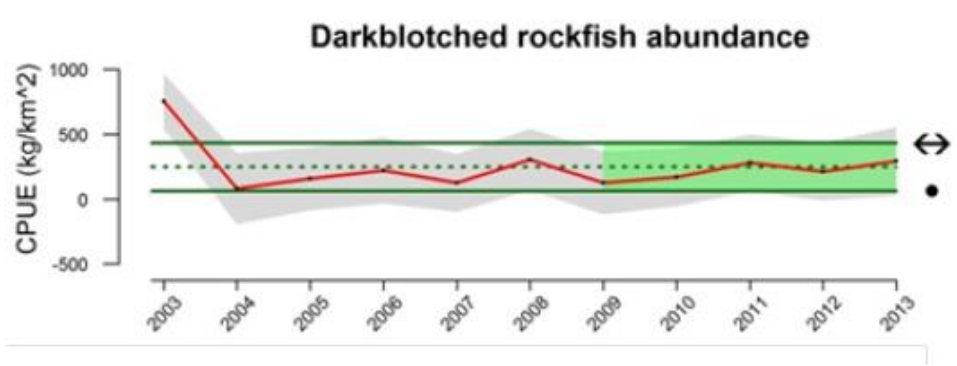


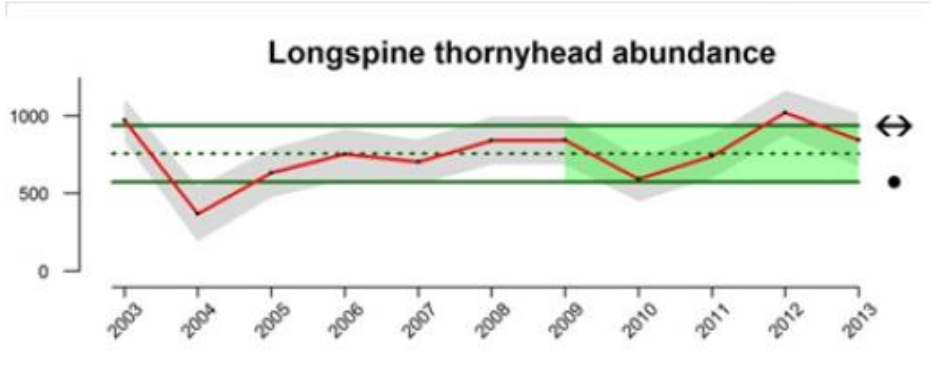
Some status & trends highlights: seafloor

- Groundfish CPUE, size/age structure were highly rated
- Crustacean CPUE and Tanner crab female condition also
- Time series are short, so should be interpreted with care; trends have been stable or increasing in WAMSP region



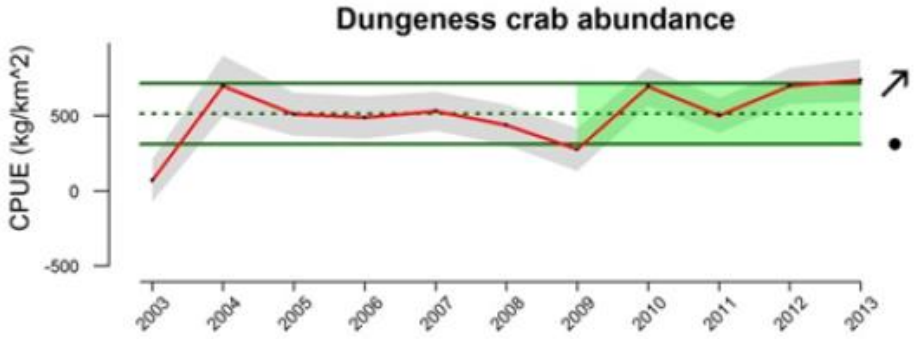


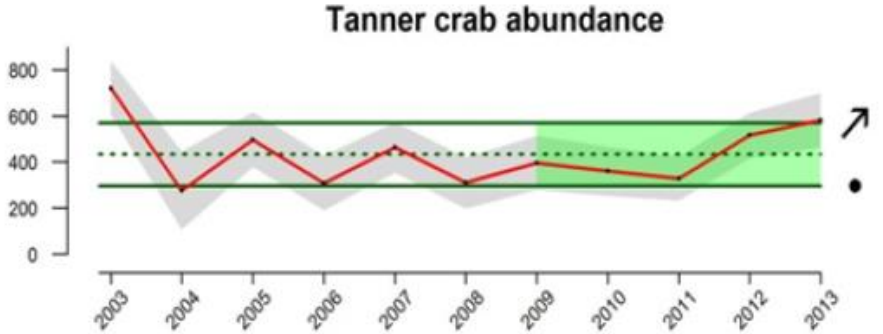


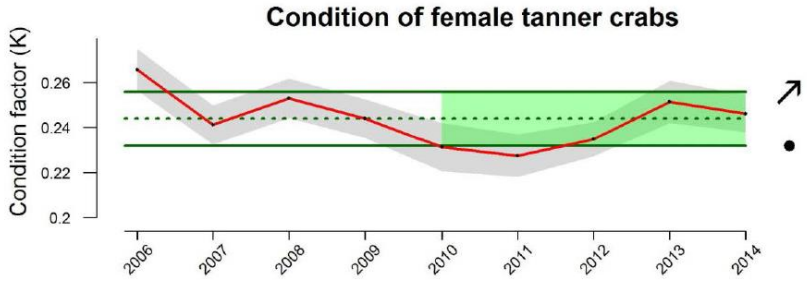


Some status & trends highlights: seafloor

- Groundfish CPUE, size/age structure were highly rated
- Crustacean CPUE and Tanner crab female condition also
- Time series are short, so should be interpreted with care; trends have been stable or increasing in WAMSP region

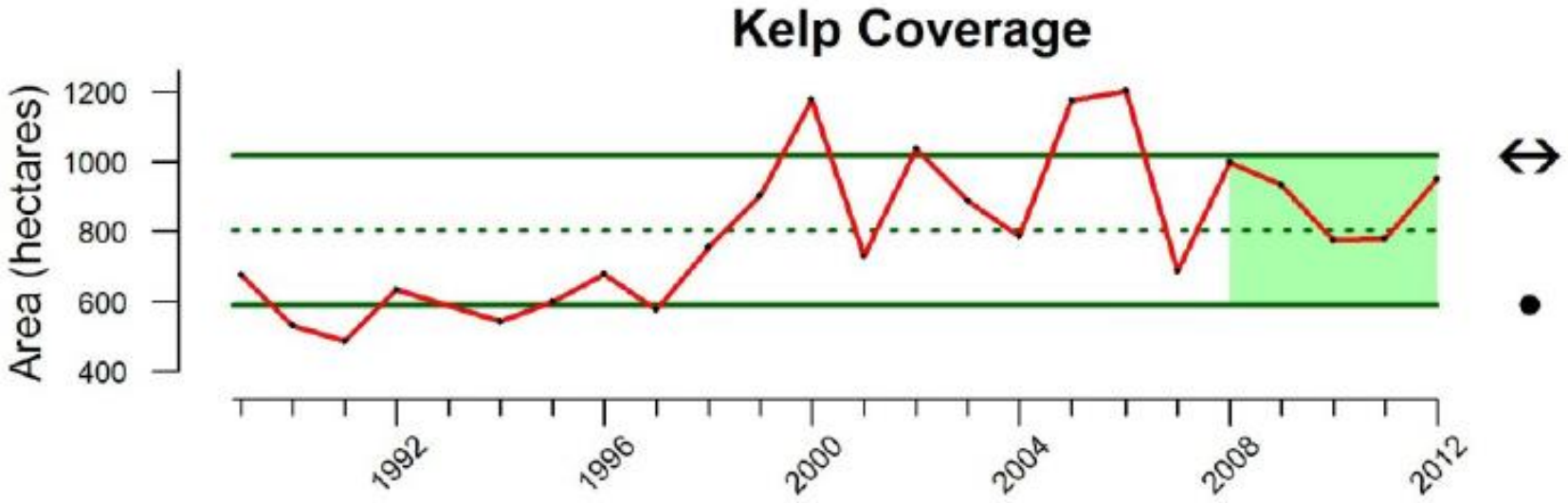






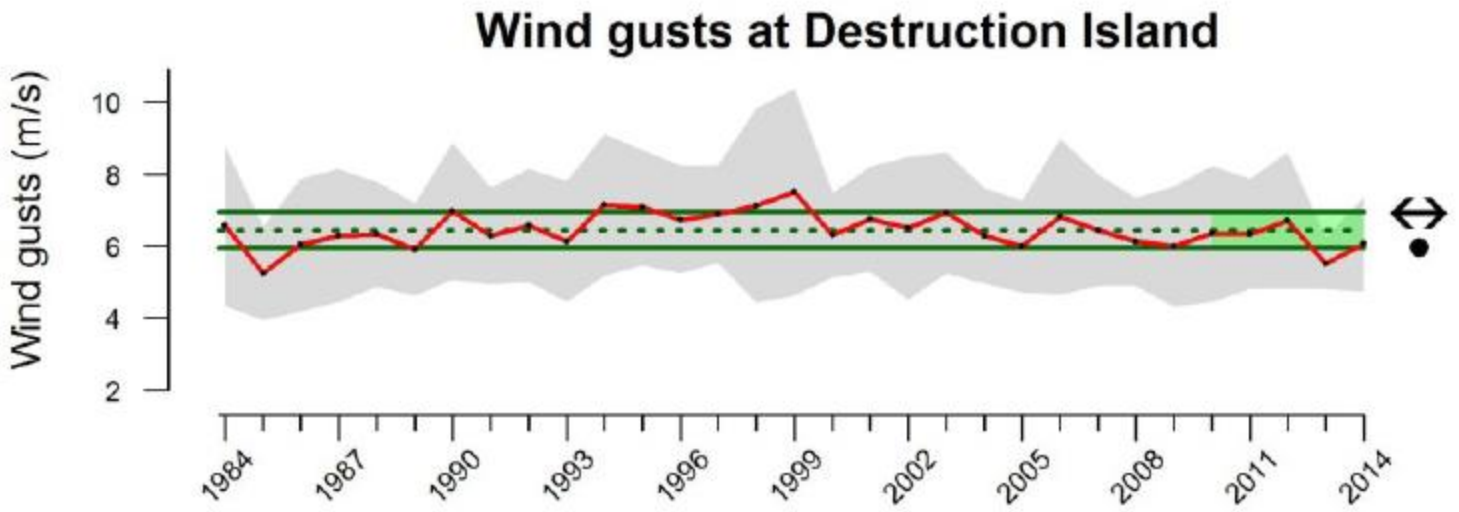
Some status & trends highlights: kelp forests

- **Kelp coverage: highly ranked indicator of habitat quantity (whew!)**
- **Coverage in WAMSP waters appears pretty stable from 2000 to 2012**



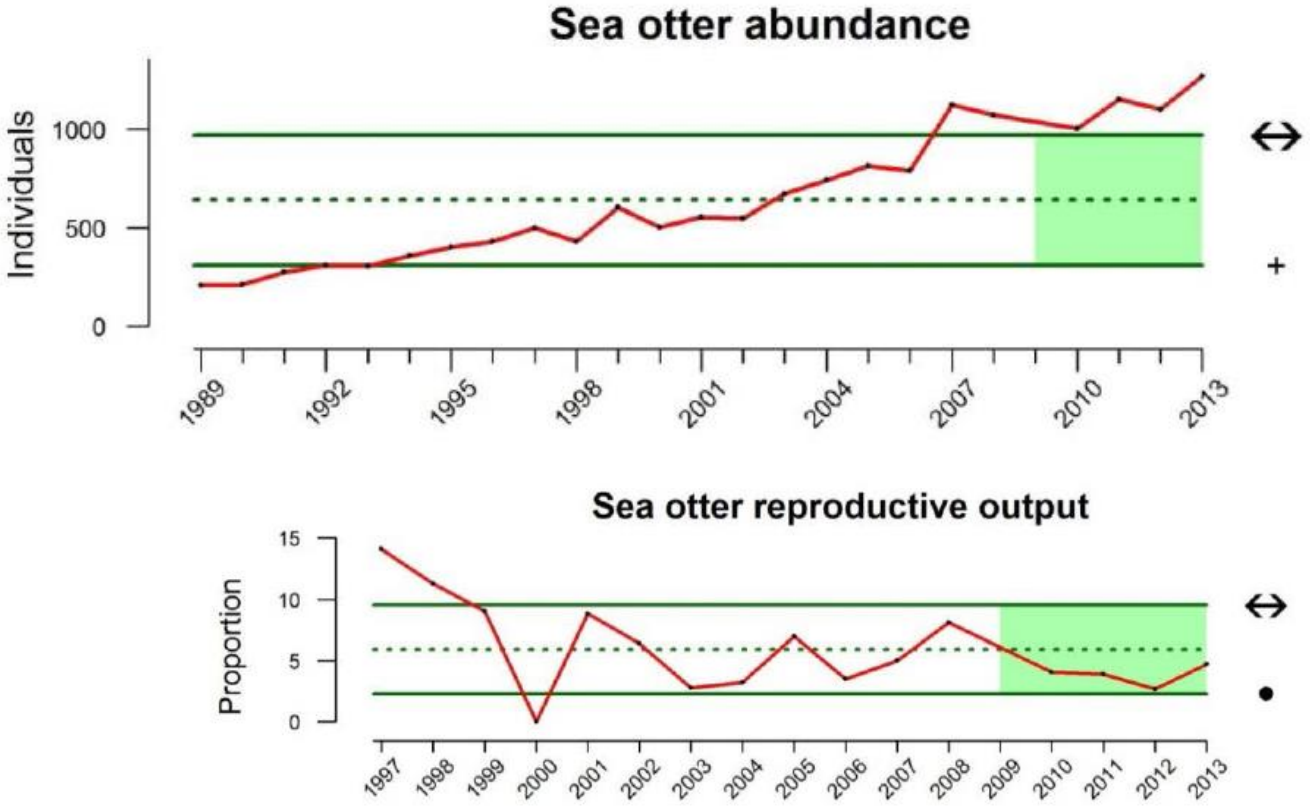
Some status & trends highlights: kelp forests

- **Wind gusts: highly rated indicator of local weather drivers**
- **Long term trend is stable but highly variable; analysis may need some refinement**



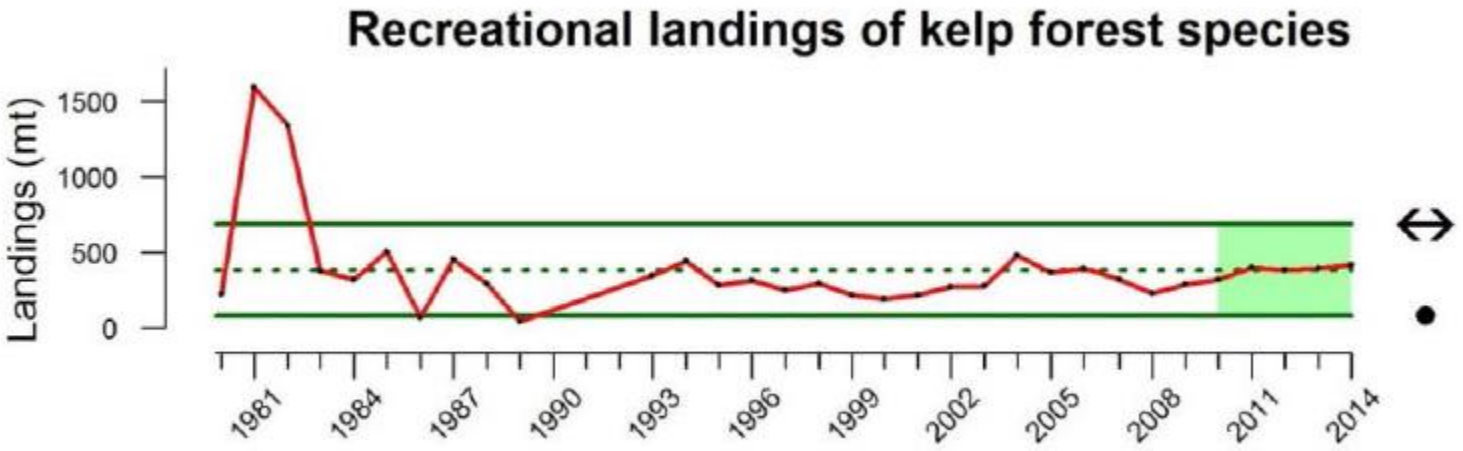
Some status & trends highlights: kelp forests

- **Sea otters: highly rated as indicator of ecological integrity**
- **Abundance stable but at (recent) historic peak, reproductive output appears stable though below historic peak**



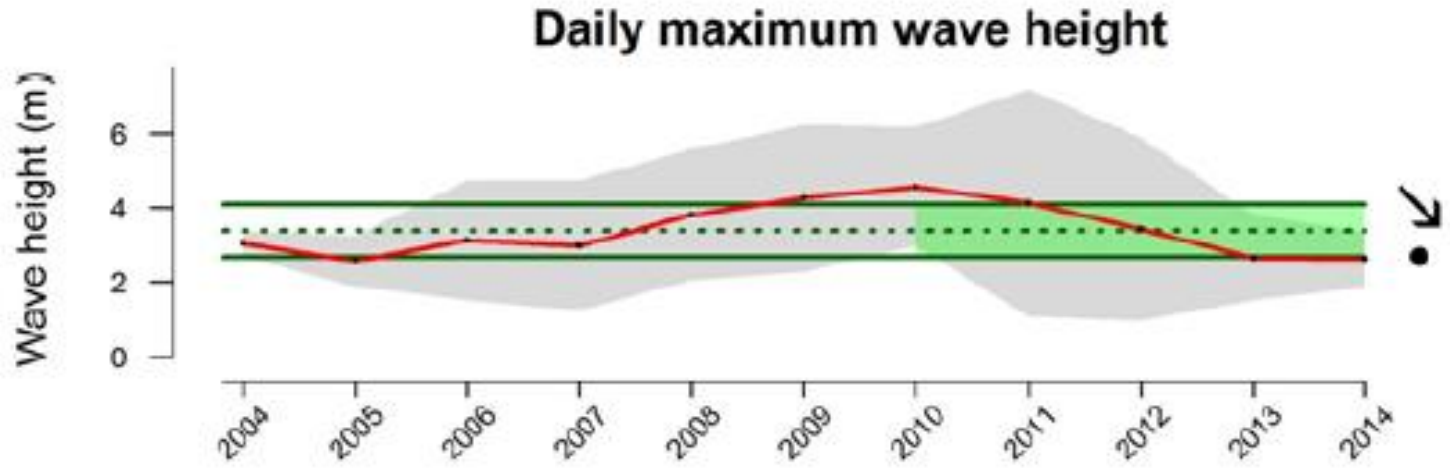
Some status & trends highlights: kelp forests

- **Recreational landings are highly rated indicator of human-derived biological extraction & mortality**
- **Recreational landings of kelp forest spp. in WA waters appears fairly stable going back to the mid 1980s**



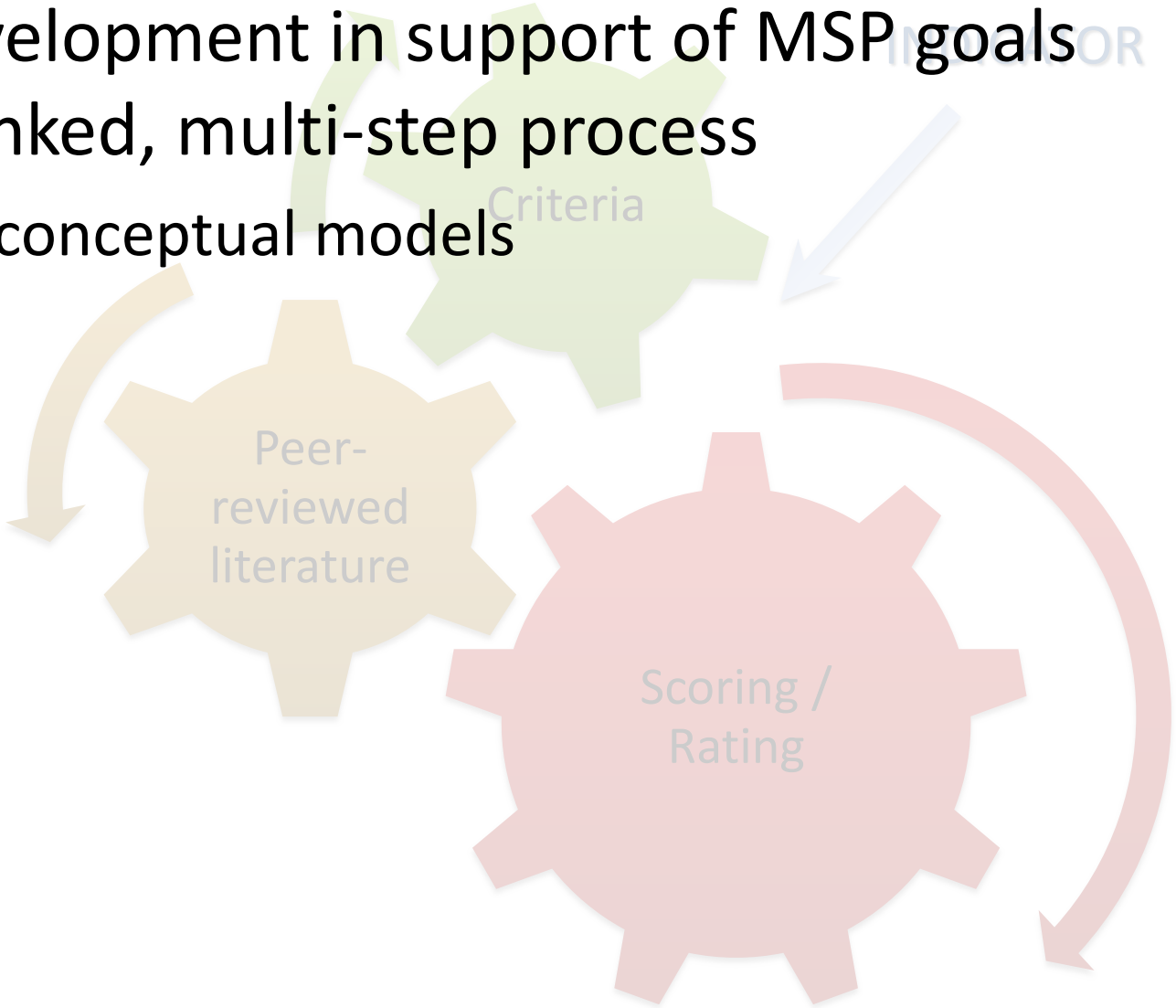
Some status & trends highlights: rocky shore

- Overall, we could only connect very few indicators to time series data, though that more likely reflects our limitations than the reality of what's out there
- One example: wave height, a highly rated indicator of local weather impacts
- Wave height @ Grays Harbor buoy trended down over last 5 yr



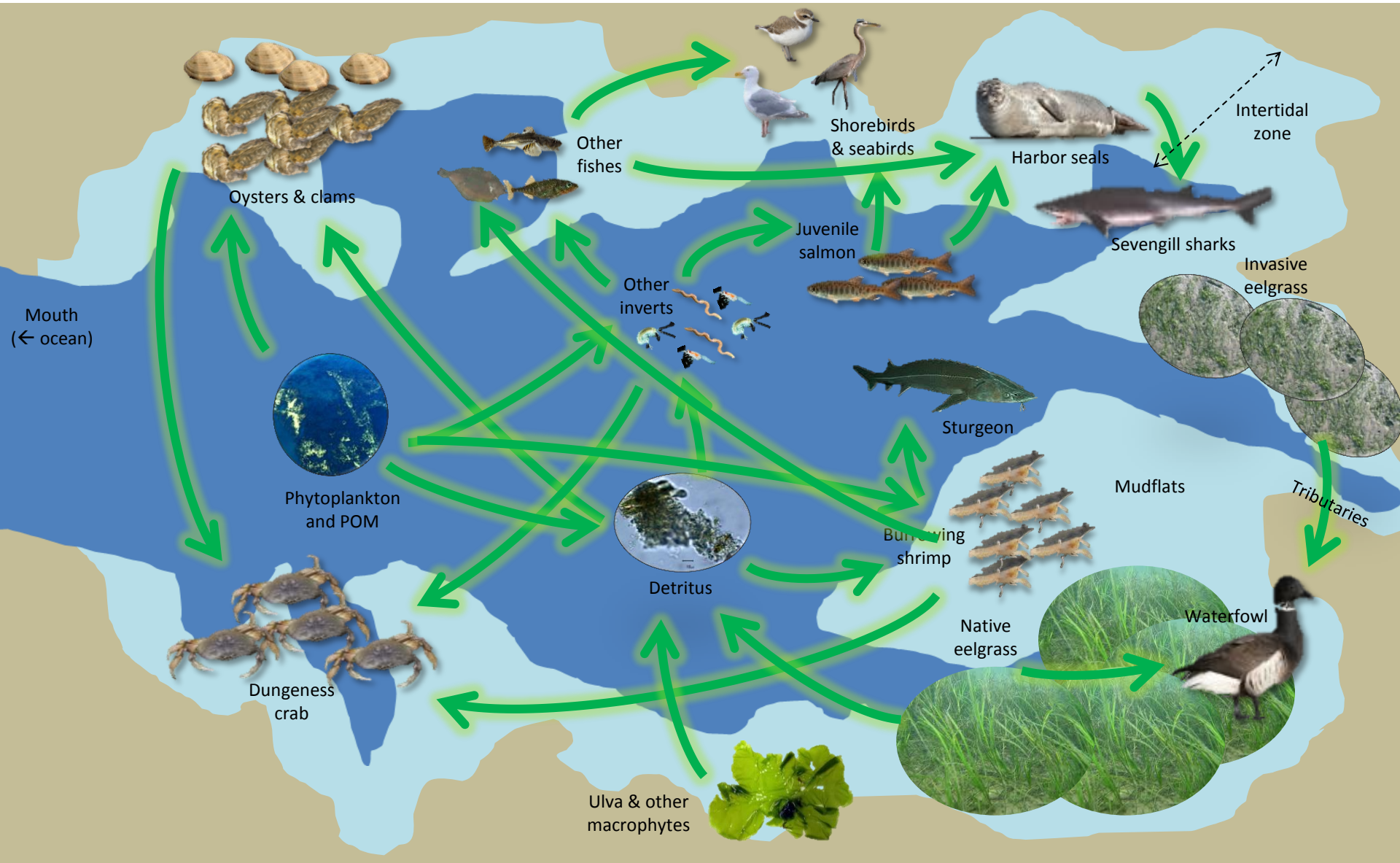
Summary

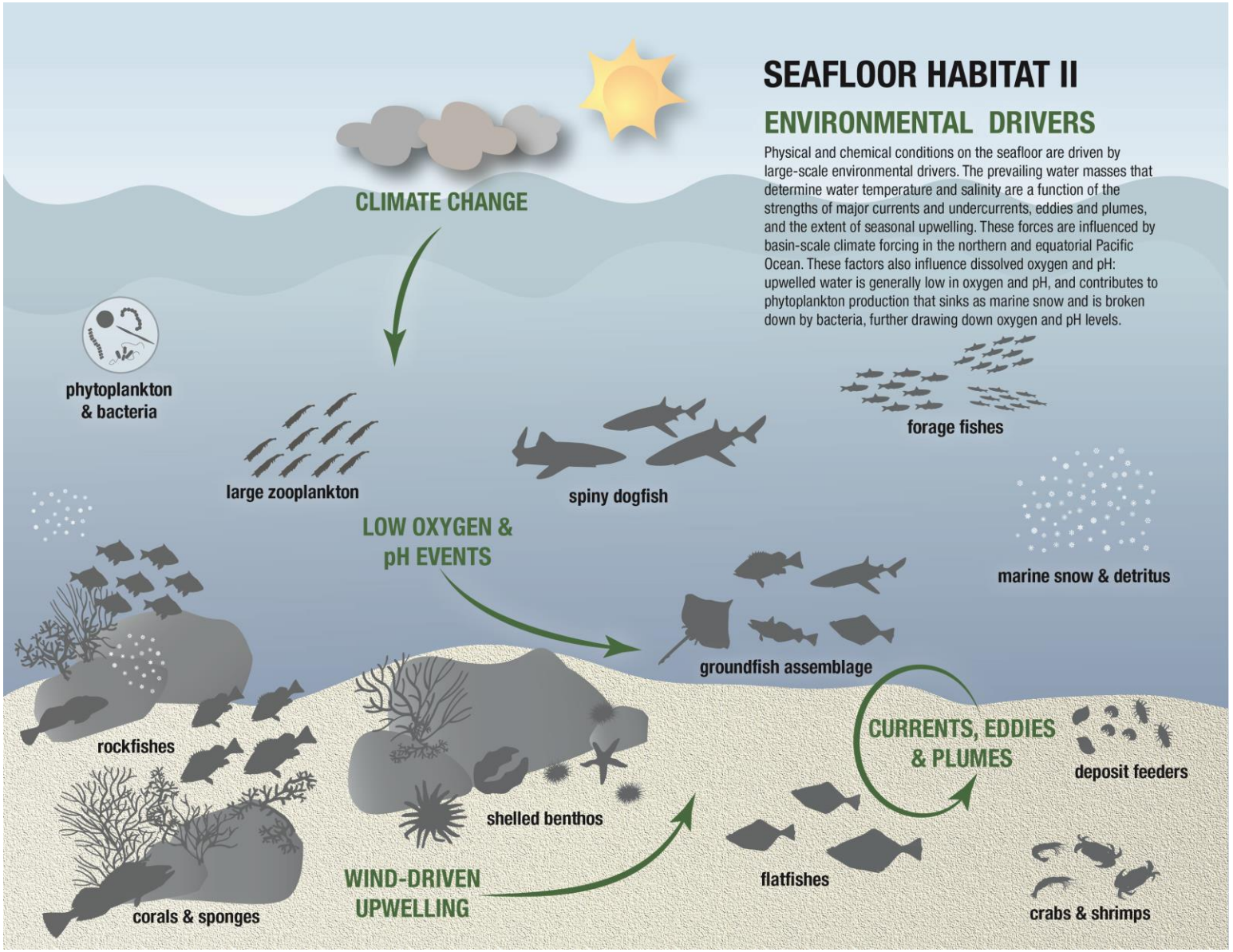
- Indicator development in support of MSP goals has been a linked, multi-step process
  - Developing conceptual models



Estuary habitat components

Food web connections





All model images by Su Kim, NWFSC

Summary

- Indicator development in support of MSP goals has been a linked, multi-step process
  - Developing conceptual models
  - Developing indicators linked to those models
    - Selection
    - Screening criteria
    - Weighting
  - Finding time series of data for highly rated indicators

  - ***Key product: sets of robust indicators that scored the highest out of all of the 100s of possibilities***

Summary

- Next steps
  - We are writing detailed appendices for each of the habitats, attributes and indicators, which we hope to complete this calendar year
  - We are closely connected to the California Current Integrated Ecosystem Assessment (IEA)
  - IEA group will be discussing how IEA methods and findings thus far can be used to inform the OCNMS Condition Report…*we want to collaborate with you!*

Summary

– Identify, close indicator and data gaps

Status and trends for all key attributes

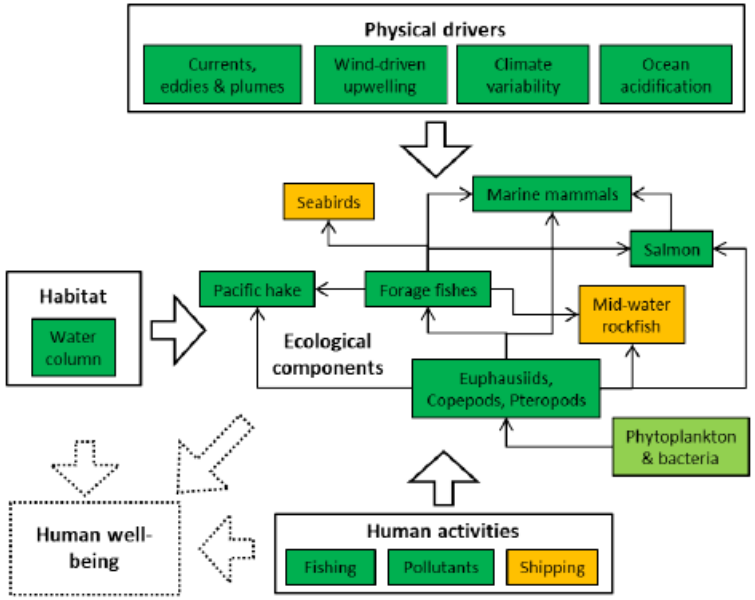
Some status and trends

Only spatial maps

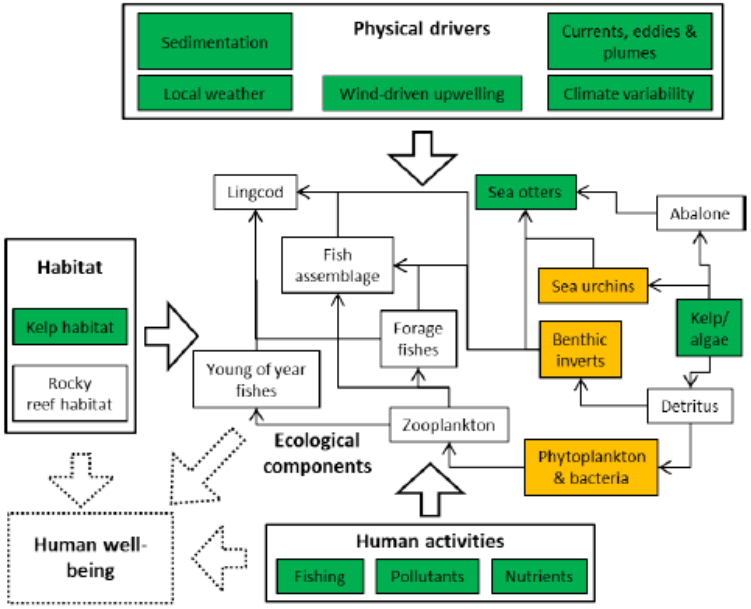
Still developing

No data sets available

Pelagic habitat



Kelp forests



Happy 21st Birthday, OCNMS!

- *This image does not reflect opinions or endorsements from NOAA*

Questions?

- Questions later? Drop us a line at:
  - Kelly.Andrews@noaa.gov
  - Chris.Harvey@noaa.gov